Baseline Ecological Risk Assessment for the Harbor Oil Study Area

Prepared for the Voluntary Group
for the Harbor Oil Site RI/FS
FINAL

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IN ASSOCIATION WITH
BRIDGEWATER GROUP, INC.

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List of Acronyms

AOC	Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAF	bioaccumulation factor
BEHP	bis(2-ethylhexyl) phthalate
BHC	hexachlorocyclohexane
BOP	Bureau of Planning
BSAF	biota-sediment accumulation factor
bw	body weight
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COI	contaminant of interest
COPC	contaminant of potential concern
CMC	criteria maximum concentration
CSM	conceptual site model
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
DQO	data quality objective
dw	dry weight
EC10	effects concentration of 10% of the organisms
EMRI	Energy & Material Recovery, Inc.
EPC	exposure point concentration
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
Facility	Harbor Oil facility
FIR	food ingestion rate
FS	feasibility study
HCID	hydrocarbon identification

HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IP	intraperitoneal
IR	ingestion rate
IRIS	Integrated Risk Information System
J-qualifier	estimated concentration
LNAPL	light non-aqueous phase liquid
LOAEL	lowest-observed-adverse-effects level
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MATC	maximum allowable toxicant concentration
MEL	Manchester Environmental Laboratory
NRNP	natural resource management plan
NOAEL	no-observed-adverse-effects level
NRC	National Research Council
OAR	Oregon Administrative Rule
OC	organic carbon
ORNL	Oak Ridge National Laboratory
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEC	probable effects concentration
PEL	probable effects level
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RFO	refined fuel oil
RI	remedial investigation
RL	reporting limit
ROC	receptor of concern
RZA	Rittenhouse-Zeman and Associates
SE/E	Sweet-Edwards/EMCON
SIR	sediment ingestion rate
SOP	standard operating procedure
SSL	soil screening level

Study Area	Harbor Oil Superfund Study Area
SUF	site use factor
SVOC	semivolatile organic compound
TEC	threshold effects concentration
TEL	threshold effects level
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-Dx	total petroleum hydrocarbons-diesel and oil extractable
TPH-G	total petroleum hydrocarbons-gasoline
TPH-HCID	total petroleum hydrocarbons-hydrocarbon identification
TRV	toxicity reference value
UCL	upper confidence limit on the mean
U-qualifier	concentration was not detected
UF	uncertainty factor
USGS	US Geological Survey
VOC	volatile organic compound
Windward	Windward Environmental LLC
ww	wet weight

EXECUTIVE SUMMARY

This document presents the baseline ecological risk assessment (ERA) for the Harbor Oil Superfund Site Study Area[1] in Portland, Oregon. The baseline ERA presents risk estimates for benthic invertebrates, terrestrial invertebrates, fish, and wildlife species that may be exposed to contaminants of potential concern (COPCs) in wetland soil, Force Lake surface sediment, Force Lake surface water, and aquatic or terrestrial biota. The risk assessment was designed to be protective of the range of species that have been observed or could use the Study Area. Conservative assumptions, such as the use of the lowest toxicity values and the use of upper confidence limit on the mean (UCL) concentrations for estimating exposure, were used in an attempt to ensure that risk estimates, although uncertain, were protective of ecological receptors.

In general, risks estimated for the aquatic benthic invertebrate community, fish, birds, and herbivorous mammals from COPCs were considered low to negligible.[2] Risk estimates for shrew from exposure to total dichlorodiphenyltrichloroethane (DDTs) in wetland soil indicated the potential for adverse effects in two localized areas within the central portion of the wetlands between the Facility and Force Lake. Wetland soil COPC concentrations were greater than soil screening levels for terrestrial invertebrates; however, because the levels are conservative thresholds intended for screening only and do not take into account site-specific bioavailability, the assessment was highly conservative.

The baseline ERA consists of separate sections on problem formulation, exposure assessment, effects assessment, risk characterization and uncertainty analysis. Each of these elements is briefly summarized in the following subsections.

ES.1 Problem Formulation

The ERA problem formulation establishes the overall scope of the assessment, which includes the identification of receptors of concern (ROCs), COPCs, and refined COPCs. Refined COPCs were further evaluated in the exposure and effects assessment, risk characterization, and uncertainty analysis.

[1] The Harbor Oil Superfund Site encompasses the Harbor Oil facility (Facility), an approximately 4.1-acre parcel of property located at 11535 N Force Avenue, the adjacent wetlands to the south and west of Force Lake, and Force Lake.

[2] Low risk is defined as NOAEL HQ is > 1.0, but LOAEL HQ is < 1.0. Negligible risk is defined as NOAEL HQ is ≤ 1.0.

A systematic process, consistent with US Environmental Protection Agency (EPA) guidance (EPA 1997a, 1998), was followed to select representative species as ROCs. This process, which was presented in the risk assessment scoping memorandum (Windward and Bridgewater 2008) and approved by EPA, resulted in the selection of species for which the risk conclusions will be protective of other species that were not explicitly evaluated. The following ROCs representing various feeding guilds were selected for this ERA:[3]

- **Invertebrates:** aquatic benthic invertebrate community and wetland invertebrate community
- **Fish:** brown bullhead (omnivorous fish) and pumpkinseed (invertivorous fish)
- **Birds:** ruddy duck (invertivorous bird), great blue heron (piscivorous bird), and red-tailed hawk (higher-trophic-level carnivorous bird)
- **Mammals:** shrew (invertivorous mammal) and Eastern cottontail (herbivorous mammal)

The problem formulation also includes a description of the data available for conducting the ERA, the suitability of the data for risk assessment purposes, and the methods for and results of using a risk-based screening process to identify COPCs. The dataset used in the baseline ERA consisted of historical data and data collected from the Study Area during two phases of remedial investigation data collection (April 2008 and April 2009). Only one of the eight historical datasets available for the Study Area was acceptable for use in this ERA. The historical data used in the ERA were collected by EPA in 2000 (Ecology and Environment 2001).

Data used in the ERA consisted of wetland surface (0 to 6 inches), intermediate (6 to 12 inches), and berm[4] (6 to 24 inches) soil chemistry data, Force Lake surface (0 to 4 inches) sediment chemistry data, Force Lake surface water chemistry data, and shallow groundwater chemistry data.[5] Contaminant concentrations in various tissue types were estimated from abiotic concentrations. The available data were found to be representative of Study Area concentrations and appropriate for use in estimating potential ecological exposures.

For each ROC selected, COPCs were identified through a conservative risk-based screening process using no-adverse-effect level or other protective toxicity thresholds from the following analyte groups: metals,

[3] Individual species selected as ROCs (e.g., brown bullhead, shrew) were selected as representative surrogate species to be protective of their respective feeding guilds (e.g., omnivorous fish, invertivorous mammals).

[4] The soil berm is approximately 2 to 3 ft high and 5 to 6 ft wide at its base and extends along the border of the Facility to the west and south; the berm is intended to prevent stormwater runoff from flowing into the adjacent wetlands.

[5] Shallow groundwater data were evaluated only as part of an exposure assessment presented in the uncertainty analysis, wherein shallow groundwater data were compared to ambient water quality criteria.

polycyclic aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs). The problem formulation also presents the conceptual site models (CSMs) for the aquatic and terrestrial ROCs. A CSM is a graphical representation of chemical sources, transport mechanisms, exposure pathways, and potentially exposed receptors. The CSM was used to define assessment endpoints and measures of exposure and effect. The significant pathways evaluated in the ERA included direct exposure to surface sediment, direct exposure to surface water, direct exposure to wetland soil, and indirect exposure through the dietary ingestion of biota. The protection and maintenance (i.e., survival, growth, and reproduction) of ROCs were the key endpoints evaluated in this assessment. Risk questions and measurement endpoints were developed for all ROCs based on the complete and significant exposure pathways identified in the CSMs.

In accordance with EPA guidance (EPA 1997a, 2001), an additional screening step was conducted to further refine the list of COPCs. In the refined screening step, Study Area concentrations were compared with background/reference area[6] concentrations to eliminate COPCs from the Study Area that had concentrations less than or equal to those in background/reference areas. This refinement step streamlined the site-specific baseline ERA, providing greater clarity and transparency to the assessment. Refined COPCs were evaluated further in the baseline ERA.

ES.2 Exposure Assessment

The exposure assessment estimates the potential exposure of each ROC/refined COPC pair identified in the problem formulation:

- The exposure of the aquatic benthic invertebrate community to refined COPCs was estimated based on concentrations in individual surface sediment samples.
- The exposure of the terrestrial invertebrate community to refined COPCs was estimated based on concentrations in individual wetland and berm soil samples.
- The exposure of fish to refined COPCs was characterized based on estimated refined COPC concentrations in fish tissue, and estimated refined COPC dietary doses using ROC-specific exposure parameters.
- The exposure of birds and mammals to refined COPCs was characterized based on estimated refined COPC dietary doses using ROC-specific exposure parameters.

In the dietary-dose evaluation for fish and wildlife ROCs, the exposure assessment presented equations and identified parameters to quantify

[6] The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA. Instead, concentrations from reference areas (urban areas in the vicinity of the Study Area) area presented for comparison with Study Area concentrations.

the ingested dose of refined COPCs. Dietary doses for fish and wildlife were estimated using available information on ROC biology and life histories, including body weight, feeding behavior, site usage, and diet. Aquatic and terrestrial tissue refined COPC concentrations were estimated from sediment and wetland soil refined COPC concentrations using biota-sediment accumulation factors (BSAFs) and bioaccumulation factors (BAFs), respectively.

ES.3 Effects Assessment

Toxicity data for potential adverse effects (i.e., reduced survival, reduced growth, or impaired reproduction), screening thresholds, and criteria were identified as outlined in the risk assessment scoping memorandum (Windward and Bridgewater 2008) and summarized in the effects assessment. Published effects thresholds were identified for the evaluation of the benthic invertebrate community exposure to sediment and terrestrial invertebrate community exposure to soil.

For fish, tissue-residue and dietary-dose toxicity reference values (TRVs) were summarized for the identified refined COPCs based on a detailed evaluation of toxicological studies in the scientific literature that documented the effects of refined COPCs on the ROCs or similar species. This literature review identified refined COPC concentrations in fish tissue and doses associated with no effects (i.e., safe concentrations or doses), in addition to the lowest concentrations or doses that indicated adverse effects. Both sets (i.e., no-observed-adverse-effect level [NOAEL] and lowest-observed-adverse-effect level [LOAEL]) of TRVs are summarized, and the rationale for TRV selection is provided.

For wildlife, dietary-dose TRVs were summarized for the identified ROC/ refined COPC pairs based on a detailed evaluation of toxicological studies in the scientific literature. Both NOAEL and LOAEL TRVs were identified; the rationale for the selection of specific values is presented.

ES.4 Risk Characterization and Uncertainty Analysis

The exposure and effects data in the risk characterization were compared to calculate hazard quotients (HQs), which were used, along with the uncertainty analysis, to assess the potential for adverse effects from specific refined COPCs. In ERAs, HQs greater than 1.0 indicate that the exposures of some ROCs are estimated to be greater than toxicological benchmarks. Such a finding is generally regarded as indication of a potential for adverse effects, particularly if the benchmark is an effects concentration (or dose) at which adverse effects were observed (i.e., a LOAEL). HQs may also be calculated based on a NOAEL. The potential for adverse effects associated with a NOAEL HQ greater than 1.0 is uncertain unless the LOAEL is also assessed, because the true threshold for effects occurs at a concentration (or dose) somewhere between the NOAEL and LOAEL. An exposure falling between the NOAEL and LOAEL may or may not result in any adverse effect. Therefore, both types of HQs are calculated and presented to better describe the potential for adverse effects.

The results for each of the ROCs are summarized in Table ES-1 and discussed below. Table ES-1 provides a summary of HQs for all ecological ROCs for which the LOAEL-based, or probable effects level (PEL)- or probable effects concentration (PEC)-based HQs were greater than 1.0. Table ES-1 presents HQs based on Study Area data as well as effects-based HQs derived using background concentrations (for metals) or reference area concentrations (for organic compounds). Note that although background concentrations have been recommended by Oregon Department of Environmental Quality (DEQ) for soils, sediment, and surface water for metals, similar recommendations are generally unavailable for organic compounds, such as DDTs, PAHs, and PCBs. For organic compounds, concentrations from reference areas (urban areas within the vicinity of the Study Area) were used for comparison with Study Area concentrations because specific background concentrations have not been established.

Table ES-1. Refined COPCs and ROCs with LOAEL-Based HQs Greater than 1.0

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Background or Reference Area LOAEL-Based HQ[a]
Aquatic Benthic Invertebrate Community			
DDD	**2.4 – 17**[b]	1.0 **– 7.2**[c]	0.072 – 0.79[c]
DDE	**6.4 – 110**[b]	**1.3 – 22**[c]	1.0 – **1.5**[c]
Terrestrial Invertebrate Community			
Chromium	**3.3 – 75**[d]		**21**[d]
Copper	0.21 – **25**[d]		0.72[d]
Zinc	0.31 – **6.2**[d]		0.72[d]
Total HPAHs	0.0056 **– 3.2**[d]		0.003 – 0.022[d]
Fish – Pumpkinseed			
Copper	**3.5**	**1.8**	0.30
Fish – Brown Bullhead			
Copper	**2.1**	**1.1**	0.18
Birds – Red-Tailed Hawk			
Total DDTs	**5.8**	**1.2**	0.020 – 0.47
Mammals – Eastern Cottontail			
Mercury	**5.9**	**1.2**	0.54
Mammals – Shrew			
Mercury	**65**	**13**	**5.7 – 15**
Total DDTs	**9.2**	**8.5**	0.053 – 0.41

[a] Background and reference area (urban areas in the vicinity of the Study Area) concentrations and sources are discussed in Attachment 4.

[b] HQs were developed based on a comparison with a TEL or a TEC.

[c] HQs were developed based on a comparison with a PEL or a PEC; total DDT concentrations were less than the total DDT PEL/PEC.

[d] HQs were developed based on a comparison with soil screening levels.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
ROC – receptor of concern
TEC – threshold effects concentration
TEL – threshold effects level

Bold identifies HQs greater than 1.0.

Aquatic Benthic Invertebrate Community: Concentrations of refined COPCs (including metals, PAHs, PCBs, and total DDTs) were greater than threshold effects concentrations (TECs) or threshold effects levels (TELs) but less than probable effects concentrations (PECs) or probable effects levels (PELs). TELs and TECs are highly conservative concentrations below which adverse effects on sediment-dwelling organisms are not expected. Exceedances of TECs and TELs do not necessarily predict toxicity; therefore, risks to benthic invertebrates are expected to be low because these COPCs had concentrations greater than TECs/TELs but less than PECs/PELs. Dichlorodiphenyl-dichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE) were the only COPCs with concentrations in sediment that were also greater than PECs or PELs (thresholds associated with adverse effects); however, total DDT concentrations were less than these thresholds, and the bioavailability of DDD and DDE would be limited because total organic carbon concentrations in the sediment were high, reducing the likelihood of effects on biota. No refined COPCs were identified for surface water; therefore, no risks to the aquatic benthic invertebrate community from exposure to surface water are expected.

As part of the uncertainty analysis, the potential exposure of aquatic benthic invertebrates to chemicals detected in nearby wetland soils and in shallow groundwater wells closest to Force Lake was evaluated. It was determined that shallow groundwater along the downgradient (i.e., south) side of the Facility is not expected to be a significant pathway of exposure for aquatic benthic invertebrates. Also, the potential for unacceptable risk to aquatic benthic invertebrates from the potential erosion of wetland soils into the lake is minimal because: 1) metals and PCB concentrations in wetland soils near Force Lake were low compared with PELs and PECs, and 2) total DDT concentrations in lake sediment were much lower than those in wetland soils likely indicating limited transport of wetland soils to Force Lake.

Terrestrial Invertebrate Community: Five refined COPCs (chromium, copper, mercury, zinc, and total HPAHs) were evaluated for the terrestrial invertebrate community. HQs were less than 6.5, except for copper (with HQs from 0.21 to 25 and a background HQ of 0.72) and chromium (with HQs from 3.3 to 75 and a background HQ of 21). This assessment likely overestimated risk because the soil screening levels are conservative thresholds intended for screening only (i.e., they are not intended to serve as cleanup values); they do not take into account site-specific bioavailability. The conservative screening level used for chromium is 21 times greater than the background soil concentration. In addition, although soil concentrations were greater than soil TRVs, earthworms were frequently observed during field sampling, including in those areas where metals concentrations were highest. The samples with concentrations greater than background concentrations and conservative screening values were relatively limited, with the highest concentrations found in wetland soils collected from or near the ditch area.

Fish: Three measures of assessment were evaluated for the two fish ROCs, pumpkinseed and brown bullhead: tissue-residue, surface water, and dietary dose. Three refined COPCs were evaluated (total PCBs in tissue and cadmium and copper in diet). Of these three COPCs, only copper had an exposure concentration greater than the LOAEL TRV, indicating the potential for adverse effects. However, the LOAEL-based HQs were low (1.8 for pumpkinseed and 1.1 for brown bullhead). Consistent with the uncertainty evaluation conducted for the aquatic benthic invertebrate community, the potential for exposure to fish from shallow groundwater discharging into Force Lake is not expected to be a significant pathway of exposure.

Uncertainties that may affect the fish ROC risk estimates include the use of literature-based BSAFs (effect on risk estimates is unknown) and the selected dietary composition for pumpkinseed (risks may be overestimated based on the assumption of aquatic benthic invertebrates prey).

Birds: For birds (ruddy duck, great blue heron, and red-tailed hawk), two COPCs (mercury and total DDTs) were evaluated based on the results of the refined COPC screen. Estimated dietary doses for mercury were less than those associated with adverse effects. The LOAEL-based HQ for total DDT for the red-tailed hawk was 1.2, indicating the potential for adverse effects.

Uncertainties that may have affected the risk estimates include the use of literature-based BSAFs and BAFs (effect on risk estimates is unknown).

Mammals: For mammals (Eastern cottontail and shrew), 11 COPCs were evaluated based on the refined COPC screen. For Eastern cottontail, LOAEL-based HQs for mercury (1.2) were greater than 1.0, indicating the potential for adverse effects. However, the background LOAEL-based HQ for mercury (0.54) was half that of the Study Area HQ, indicating that background contributions to the risk estimate were significant.

For shrew, LOAEL-based HQs for mercury (13) and total DDTs (8.5) were greater than 1.0, indicating the potential for adverse effects. The background LOAEL-based HQs for mercury ranged from 5.7 to 15 (compared with a Study Area HQ of 13), indicating that background concentrations are an important consideration for mercury. Reference area LOAEL-based HQs for total DDTs were less than 1.0.

Uncertainties that may affect the mammal risk estimates include the site use of shrew and the use of literature-based BAFs and BSAFs.

To further evaluate risks to shrew from total DDTs, a map was created to evaluate the spatial extent of areas with concentrations that resulted in LOAEL-based HQs greater than 1.0. Shrew were assumed to consume both aquatic and terrestrial invertebrates; however, the majority of their COPC exposure (> 99%) can be attributed to total DDT concentrations in wetland soil (i.e., through the terrestrial food chain). Wetland areas with total DDT concentrations that resulted in area-wide HQs greater than 1.0 were limited to a few highly localized areas, generally within the central portion of the wetlands between the Facility and Force Lake.

1.0 INTRODUCTION

1.1 Document Purpose and Scope

On May 31, 2007, the Portland General Electric Company, Bonneville Power Administration, Avista Corporation, NorthWestern Corporation, Union Oil Company of California, and Waste Management Disposal Services of Oregon, Inc. (Voluntary Group for the Harbor Oil Site Remedial Investigation/Feasibility Study [RI/FS] [Voluntary Group]) entered into an Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study (AOC), Docket No. CERCLA-10-2007-0106, with the US Environmental Protection Agency (EPA) for the Harbor Oil Superfund site (Site) in Portland, Oregon. In accordance with the AOC, the Study Area encompasses the Harbor Oil facility (Facility), an approximately 4.1-acre parcel of property located at 11535 N Force Avenue, the adjacent wetlands to the south and west of the main facility and Force Lake. The AOC statement of work requires that the Voluntary Group prepare an RI that includes a baseline ecological risk assessment (ERA).

This document presents the baseline ERA for the Study Area and includes the following sections:

- Section 2.0, Problem Formulation
- Section 3.0, Exposure Assessment
- Section 4.0, Effects Assessment
- Section 5.0, Risk Characterization
- Section 6.0, Conclusions
- Section 7.0, References

The parameters used to assess risks in this ERA are considered to be conservative regarding exposure and effects, as is appropriate for a baseline ERA, to ensure adequate protection of ecological receptors. The ERA was designed to be protective of the range of species that have been observed or could use the Study Area. Conservative assumptions, such as the use of the lowest toxicity values and the use of upper confidence limit on the mean (UCL) concentrations for estimating exposure, were employed to be protective.

1.2 Study Area Location and Facility Description

This section briefly describes the Study Area, as discussed in the RI/FS Work Plan (Bridgewater et al. 2008b). The Study Area is located in north Portland, Multnomah County, Oregon, and includes the Facility, adjacent wetlands to the south and west of the Facility, and Force Lake (Figure 1-1).

Figure 1-1. Harbor Oil Study Area

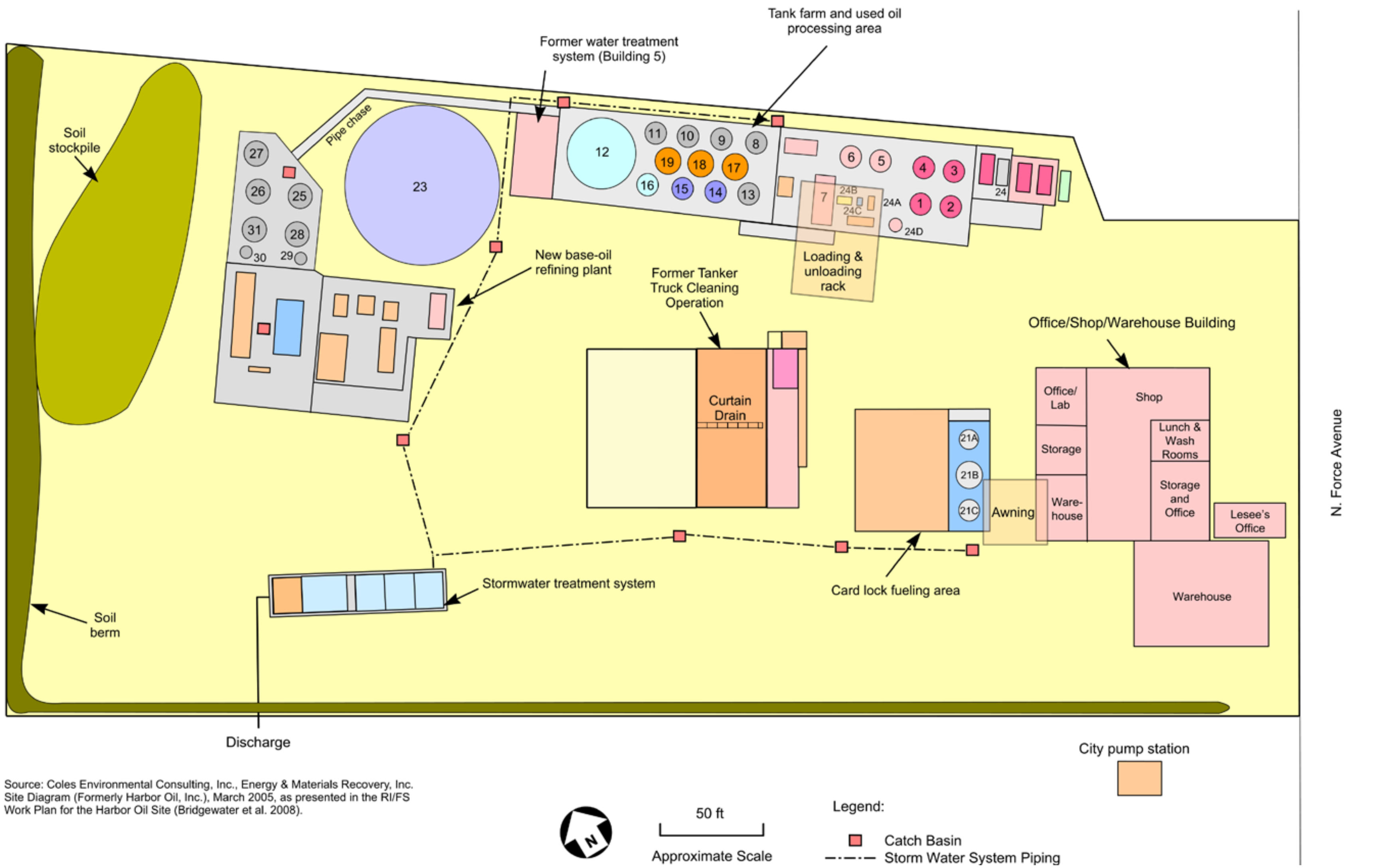
According to Coles Environmental Consulting, Inc. (2002), Energy & Material Recovery, Inc. (EMRI), currently operates a waste treatment and processing facility for used oil, oily water, and other wastewater at the Facility. EMRI's office/shop/warehouse building is located on the southeast side of the Facility, near the main entrance along N Force Avenue (Figure 1-2). A portion of this building is also used by Wevco Biodiesel Products LLC for the manufacture of biodiesel. Another portion of the building is occupied by Phoenix Asphalt, an asphalt coating business. Immediately to the west of the building is a card-lock fueling station operated by another tenant of EMRI. Until recently, most of the Facility was unpaved and covered with gravel. However, during the fall of 2011, the majority of the Facility (all areas except for the western-most portion of the Facility) was paved with asphalt.

Historically, the production of refined fuel oil (RFO) was carried out at a tank farm and used-oil processing area located along the northeast side of the Facility. Wastewater from the RFO process was historically discharged to Tank 12 (located at the northwest end of the tank farm and used oil processing area) for storage and then discharged to Tank 23 for treatment. Tank 23 is no longer used. Currently, the RFO is further processed in a base oil refining plant that was constructed in 2003 (west of the tank farm). Soils excavated during the construction of the base oil refining plant were stockpiled to the northwest of the plant, hereafter referred to as the soil stockpile (Figure 1-2).

A structure in the central area of the Facility was previously used as a tanker truck cleaning operation. The western portion of this structure is currently leased to the asphalt coating business, and the eastern portion is used by EMRI for vehicle and equipment storage.

A soil berm that is approximately 2 to 3 feet high and 5 to 6 feet wide at its base extends along the border of the Facility to the west and south; the berm is intended to prevent stormwater runoff from flowing into the adjacent wetlands (Figure 1-2). As stated in the RI/FS Work Plan (Bridgewater et al. 2008b), the soil berm was constructed shortly after a fire that occurred at the Facility in 1979.

A narrow stretch of natural forested wetlands borders the Facility to the south and west (Figure 1-1), separating the Facility from Force Lake. The lake is bordered on the east by N Force Avenue and on the south and west by the Heron Lakes Golf Course. There are two known direct discharge points into Force Lake: a catch basin that drains a small area along the east side of N Force Avenue and an underdrain for one of the greens on the golf course (Goodling 2007). The Facility's existing stormwater treatment system does not discharge directly to the lake but instead drains into the wetlands just south of the Facility. Force Lake drains through two culverts to North Lake, which is northwest of Force Lake and is connected to a series of ditches and other water bodies located on the golf course.



Source: Coles Environmental Consulting, Inc., Energy & Materials Recovery, Inc. Site Diagram (Formerly Harbor Oil, Inc.), March 2005, as presented in the RI/FS Work Plan for the Harbor Oil Site (Bridgewater et al. 2008).

Figure 1-2. Current Facility Features

2.0 Problem Formulation

This section presents the problem formulation for the baseline ERA. Through the use of a risk-based screening approach, the problem formulation establishes which receptor of concern (ROC) and contaminant of potential concern (COPC) pairs are further evaluated in the exposure and effects assessment, the risk characterization, and the uncertainty analysis. This section includes information regarding the environmental setting (Section 2.1), ecological resources that use the Study Area (Section 2.2), selection of ecological ROCs (Section 2.3), summary of relevant and acceptable data collected from the Study Area used in the ERA (Section 2.4), the conceptual site model (CSM) for the Study Area (Section 2.5), and the selection of COPCs through a two-step process (Sections 2.6 and 2.7). Together, these elements establish the scope for this ERA according to EPA guidance (EPA 1997a, 1998).

2.1 Environmental Setting

The Study Area includes the Facility (where ecological exposure is assumed to be negligible because of the gravel cover[7] and pavement that covers the Facility), the adjacent wetlands, and Force Lake. The Facility, adjacent wetlands, and Force Lake are a small part of the area covered by a natural resources management plan (City of Portland 1997) established by the City of Portland for a 900-acre area called Pen 1. This area is within the larger Columbia River watershed located between the Columbia River and the Columbia Slough. The information collected as part of the natural resource management plan in 1997 by the City of Portland is expected to still be representative of current conditions at the Harbor Oil Study Area based on observations during site visits and during RI/FS sampling and the fact that land use has not changed significantly over the past 15 years.

Three primary habitats were classified within Pen 1 (which, as noted, covers a much larger area than the Study Area): emergent wetlands (marshes), open water sloughs, and forested wetlands (City of Portland 1997). A variety of plant species are found within these habitat areas. Black cottonwood trees, which are found within the emergent wetlands and forested wetlands and near open water sloughs, provide high-quality wildlife habitat for nesting and foraging. Willows are also a dominate tree species found in the forested and emergent wetland habitat areas. Dense stands of Himalayan blackberry dominate the open-water slough shrub community; wetland habitats include a more diverse plant community that includes reed canary grass, soft rush, cattails, beggar’s tick, sedges, soft stem bulrush, speedwell, and various species of grasses (City of Portland 1997).

[7] The gravel cover is approximately 12 inches thick in most locations where present.

Approximately 1 mile of wetland frontage and approximately 40 acres of emergent wetlands are associated with Force Lake (DEQ 1995; as cited in Ecology and Environment 2001). A narrow stretch of natural forested wetlands borders the Facility to the south and west, providing habitat for wetland and terrestrial species. The large wetland area to the west of the Facility is classified as an emergent wetland. The dominant plant species in this riparian/wetland area are reed canary grass, black cottonwood, and willow trees (City of Portland 1997).

Force Lake provides aquatic wildlife for various species and habitat for a stunted fishery for a few fish species. The lake is 590 to 890 feet in diameter with a surface area of about 12 acres and an estimated storage volume of about 30 acre-feet (City of Portland 1997).The depth of Force Lake ranges from approximately 2 to 6 feet, with an average depth of 2 to 3 feet (Fishman 1989). The lake's vegetation is relatively homogenous, mostly consisting of reed canary grass and soft rush (City of Portland 1997). Force Lake drains through two culverts to North Lake, which is connected to a series of ditches and other water bodies in the Pen 1 area.

The Heron Lakes Golf Course is located next to Force Lake and the wetlands area. A great blue heron rookery is located approximately one-half mile to the west of the Study Area at the edge of an emergent/forested wetland area.

2.2 Resources Potentially at Risk

A number of species may use the habitat in Force Lake and in the wetland areas adjacent to the Facility. This section presents a summary of the available information on the use of the wetland areas by these species. For the purpose of this discussion, species have been divided into four groups: invertebrates, fish, birds, and mammals.

2.2.1 Invertebrates

Both aquatic benthic invertebrates and terrestrial invertebrates are present in habitat areas adjacent to the Facility. Aquatic invertebrates are prey for higher-trophic-level organisms (fish and invertivorous birds) in Force Lake, and terrestrial invertebrates are prey for organisms such as foraging invertivorous mammals in the surrounding wetland habitat. There are no known studies that have investigated the invertebrate communities in Force Lake or the wetlands adjacent to the Facility, although earthworms were observed in wetland soil during the RI sampling in 2008 and 2009.

2.2.2 Fish

Fishman (1989) conducted a fisheries evaluation of Force Lake in August 1988 and March 1989 through the use of electroshocking, beach seining, and trapping. Windward Environmental LLC (Windward) conducted a fish survey in April 2009 using electroshocking, minnow traps, and a fyke net (Windward 2009b).

The April 2009 survey was conducted to obtain information on the types of fish present in the lake and estimate the abundance and sizes of these fish (Windward 2009b). The survey was conducted in accordance with the fish survey sampling design memorandum approved by EPA (Windward 2009a) and used several collection methods under good conditions[8] to provide a representative picture of the fish population present in Force Lake.

Three species were caught during the April 2009 survey (Windward 2009b): carp, pumpkinseed, and brown bullhead (Table 2-1). No game fish (e.g., trout or bass) or native fish were caught or observed during the survey. A total of 88 fish were collected, approximately 86% of which were 14 cm (5.5 inches) in length or less. Fifty-four carp were caught, only twelve of which were greater than 14 cm (5.5 inches) in length. Thirty-three pumpkinseed were caught, all of which were less than 12 cm (4.7 inches); the only brown bullhead caught was 6.7 cm (2.6 inches) in length.

The April 2009 survey results are generally consistent with the results of an earlier survey conducted in the late 1980s (Fishman 1989). In that survey (conducted on August 5, 1988, and March 13, 1989), 22 bluegill were collected; the length of most of the bluegill collected (2.5 to 4.4 cm [approximately 1 to 1.7 inches]) indicated that they were juvenile fish. Over 1,000 unidentified juvenile sunfish (bluegill or pumpkinseed) were also collected, along with moderate numbers of carp (n = 4), goldfish (n = 9), pumpkinseed (n = 7), and brown bullhead (n = 18). More than 2,000 mosquitofish were collected in 1988, indicating a high density of this fish in the late 1980s when ponds and lakes were stocked with this species for mosquito control. However, only one mosquitofish was collected in 1989. All of the fish identified in both the April 2009 survey and Fishman (1989) survey are omnivorous benthic or benthopelagic fish, with the exception of mosquitofish, which prey primarily on invertebrates.

[8] Lake conditions conducive to an optimal catch-per-unit effort during the fish survey included a moderate water temperature, good water clarity, shallow water depth, and lack of habitat to provide cover for the fish.

Table 2-1. Fish Species Identified in Force Lake in 1988-1989 and 2009

Common Name	Scientific Name	Feeding Guild	Juvenile Diet	Adult Diet	Number and Lengths of Fish Caught in Force Lake	
					1988-1989 Fish Survey[a]	2009 Fish Survey[b]
Brown bullhead	*Ameiurus nebulosus*	omnivore	chironomid larvae, cladocerans, ostracods, amphipods, insects (Scott and Crossman 1973)	benthic macroinvertebrates, detritus, and small fish (Scott and Crossman 1973; Wydoski and Whitney 2003)	18 (5.5 to 26 cm)	1 (6.7 cm)
Goldfish	*Carassius auratus*	omnivore	zooplankton, plants (Wydoski and Whitney 2003)	plants, small crustaceans, insects, and detritus (Wydoski and Whitney 2003)	9 (5.9 to 11.4 cm)	none
Pumpkinseed	*Lepomis gibbosus*	omnivore	no data	aquatic insects, mollusks, crustaceans (Wydoski and Whitney 2003)	7 (8.7 to 12.3 cm)	33 (7.6 to 10.3 cm)
Bluegill	*Lepomis macrochirus*	omnivore	zooplankton, aquatic insects, fish eggs (Wydoski and Whitney 2003)	aquatic insects, mollusks, crayfish, amphipods, fish eggs (Scott and Crossman 1973; Wydoski and Whitney 2003)	22 (2.5 to 14 cm)	none
Carp	*Cyprinus carpio*	omnivore	zooplankton, plants (Wydoski and Whitney 2003)	algae, vegetation, clams, insects, zooplankton (Wydoski and Whitney 2003)	4 (30 to 45.7 cm)	54 (6.4 to 21.8 cm)
Mosquitofish	*Gambusia affinis*	invertivore	insect larvae, diatoms, zooplankton (Wydoski and Whitney 2003)	insects, aquatic benthic invertebrates, diatoms (Sandercock 1991; Page and Burr 1991)	August: > 2,000 (< 2 cm) March: 1 (4 cm)	none

[a] Fishman (1989).
[b] (Windward 2009b).

The change in the bullhead population since the 1988/1989 Fishman study to the 2009 survey may indicate either a change in the Force Lake habitat and/or that the lake was stocked with bullhead in the past. Jesse Goodling, Heron Lakes Golf Course Superintendent, noted that since 1986, when he started working at the golf course, the water level in Force Lake during at least two different years was low enough to expose part of the lake bottom, typically at the end of a hot, dry summer. The last time this happened (4 or 5 years ago), Mr. Goodling recalled seeing a number of dead fish floating in the lake, possibly because of an algae bloom, which would depress oxygen levels in Force Lake. This type of event could have been responsible for altering the fish species present in Force Lake.[9]

Based on the characteristics noted during the 2009 fish survey (Windward 2009b) (e.g., 2-to-3-ft average water depth and lack of habitat to provide cover), Force Lake would be categorized as a small, shallow lake. Force Lake has a uniformly muddy bottom, with little overhanging shoreline vegetation or other cover. The limited vegetative cover present at Force Lake is along the shoreline, generally in areas where the water depth is less than 2 ft. These habitat conditions are not conducive to large fish populations or to populations of fish such as trout or bass, which were not observed. The species that were observed during the 2009 fish survey (Windward 2009b) (predominantly carp and pumpkinseed) are the types of fish that would be able to survive and reproduce in the less-than-ideal habitat found in Force Lake, although the population of these species would be small.

In small lakes such as Force Lake, the absence of large predators (e.g., bass) results in relatively dense populations of fish that are stunted in size because of the greater competition for food (Scheffer 1998). Larger predators change the species structure in lakes by consuming juvenile fish and allowing the remaining individuals to grow larger because there is less competition for food resources.

Despite the fact that the lake was stocked with 300 juvenile channel catfish during the summer of 2005 or 2006[10] (Alsbury 2008; Egan 2008), no catfish were caught or observed during the survey, indicating that they were either all caught or the habitat is not suitable for sustaining a population, or both. Only one small juvenile brown bullhead (6.7 cm in length), a species related to channel catfish,[11] was caught, indicating that Force Lake does not provide the appropriate habitat for these fish to reproduce in large numbers.

[9] Information provided to Stu Brown (The Bridgewater Group) by Jesse Goodling in July 2009.

[10] Information on the stocking of the lake with 300 channel catfish is based on information provided by both Bill Egan (program director, Oregon Bass and Panfish Club) and Todd Alsbury (district biologist for ODFW) during phone conversations on December 19, 2008. The exact date these fish were stocked is not known. It is suspected that the stocking occurred during the summer of 2005, but it may have occurred during the summer of 2006.

[11] Brown bullhead and channel catfish are related species (both in the *Ictaluridae* family).

2.2.3 Birds

Numerous bird species inhabit Force Lake and the surrounding area. Tables 2-2 and 2-3 present the bird species observed on or near Force Lake and observed within the 900-acre Pen 1 area based on the City of Portland Bureau of Planning (BOP) survey conducted in 1997 (City of Portland 1997). Fifty-five bird species have been observed on or near Force Lake (Table 2-2), and an additional 36 bird species have been observed within Pen 1 (Table 2-3).

Birds from the following general feeding guilds have been observed:

- **Herbivorous birds:** including dabbling and diving ducks
- **Insectivorous/invertivorous birds:** including sediment-probing invertivores, birds that feed on flying insects, and terrestrial birds and aquatic ducks that feed on aquatic insect larvae and aquatic benthic invertebrates, respectively
- **Piscivorous birds:** including aquatic birds that feed predominately on fish
- **Carnivorous birds:** including terrestrial birds of prey that consume species at higher trophic levels (i.e., birds and mammals)
- **Omnivorous birds:** including birds with an opportunistic diet or a non-specific diet that includes plants and various prey species

Table 2-2. Birds Observed on or Near Force Lake

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Canvasback	*Aythya valisineria*	herbivore	seeds and tubers of pondweed, along with a variety of other plants; may substitute mollusks or other shellfish when plants are not available	
American wigeon	*Anas americana*	herbivore	plants (mostly grasses and clover); may also eat fish eggs	winter in various areas, including at Force Lake
Ring-necked duck	*Aythya collaris*	herbivore	plant-based diet	
Gadwall	*Anas strepera*	herbivore	primarily aquatic plants and seeds, with invertebrates becoming important during the breeding season	
Band-tailed pigeon	*Columba fasciata*	herbivore	diet varies seasonally by location; includes buds, flowers, and fruits of deciduous trees and shrubs	
American goldfinch	*Carduelis tristis*	herbivore	seeds; also feeds opportunistically on grasses, insects, and fruit tree buds	
Dark-eyed junco	*Junco hyemalis*	herbivore	mostly seeds, some insects, especially during nesting season	
Eurasian wigeon	*Anas penelope*	herbivore	prefer leaves and plant material (mostly grasses and clover); may also eat fish eggs	
Canada goose	*Branta canadensis*	herbivore	aquatic and terrestrial plants (e.g., grasses)	
Cedar waxwing	*Bombycilla cedorum*	herbivore	prefers fruit, will also eat insects and flowers; during mating period, up to one-quarter of diet may be insects	
Downy woodpecker	*Picodes pubescens*	insectivore	mostly insects, beetles and spiders, and some plant matter	
Tree swallow	*Tachycineta bicolor*	insectivore	insects; including gnats, flies and beetles; also will prey on mayflies and ants	
Violet-green swallow	*Tachycineta thalassina*	insectivore	insects; including leafhoppers, leafbugs, flies, ants, and beetles	
Northern rough-winged swallow	*Stelgidopteryx serripennis*	insectivore	flying insects; including ants, bees, wasps, flies, and beetles	
Orange-crowned warbler	*Vermivora celata*	insectivore	mostly insects; sometimes take fruit in winter	

Table 2-2. Birds Observed on or Near Force Lake

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Bushtit	*Psaltriparus minimus*	insectivore	mostly insects (including plant lice, bark lice, and spiders); some plant matter	
Golden-crowned kinglet	*Regulus satrapa*	insectivore	insects from branches of trees	
Barn swallow	*Hirundo rustica*	insectivore	opportunistic forager of insects, primarily flies, beetles, leafhoppers, and ants	
Rudy-crowned kinglet	*Regulus calendula*	insectivore	insects, including wasps, ants, bugs, beetles, adult and larval butterflies and moths, flies, and spiders; also feeds on plant material (fruit and seeds)	
Vaux's swift	*Chaetura vauxi*	insectivore	insects, including flies, ants, bees, planthoppers, aphids, spindlebugs, lanternflies, beetles, moths, and spiders	
Northern shoveler	*Anas clypeata*	invertivore	primarily crustaceans and invertebrates; occasionally consumes plant seeds	
Common yellowthroat	*Geothlypis trichas*	invertivore	insects and invertebrates	
American robin	*Turdus migratorius*	invertivore	earthworms and beetles; occasionally feeds on fruits and berries	
Spotted sandpiper	*Aetitis macularia*	invertivore	invertebrates (including terrestrial and aquatic prey such as flying insects, insect larvae, grasshoppers, crickets, grubs, worms, beetles), young fish, and small crustaceans	
Fox sparrow	*Passerella iliaca*	omnivore	insects, spiders, seeds, and berries	
White-crowned sparrow	*Zonotrichia leucophrys*	omnivore	arthropods, seeds, grass, fruit, and buds	
Spotted towhee	*Pipilo maculatus*	omnivore	insects during the breeding season and seeds in winter	
Red-winged blackbird	*Agelaius phoenecius*	omnivore	cultivated grain, seeds, insects, and beetles	
Song sparrow	*Melospiza melodia*	omnivore	insects, grass and weed seeds, fruits, and berries, and possibly even small minnows	
Black-capped chickadee	*Poecile atricapilla*	omnivore	caterpillars, spiders, snails, slugs, centipedes, insect eggs, seeds, and fruit	
Sora	*Porzana carolina*	omnivore	weeds, insects, plant leaves and stems, and aquatic invertebrates	

Table 2-2. Birds Observed on or Near Force Lake

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Virginia rail	*Rallus limicola*	omnivore	worms, insects, caterpillars, spiders, slugs, snails, small aquatic invertebrates, small fish, amphipods, crustaceans, frogs, small snakes, aquatic plants, and seeds	
Wood duck	*Aix sponsa*	omnivore	seeds, shrubs, aquatic plants, and fruits	
American coot	*Fulica americana*	omnivore	aquatic vegetation, aquatic invertebrates; may feed on eggs and prey on young of other birds	
Ring-billed gull	*Larus delawarensis*	omnivore	insects, fish, small mammals, earthworms, crustaceans, garbage, and grain	
Cinnamon teal	*Anas cyanoptera*	omnivore	aquatic plants, mollusks, invertebrates (midges and larvae)	
American crow	*Corvus brachyrhynchos*	omnivore	seeds, nuts, berries, caterpillars, frogs, mice, bird eggs, nestlings, and garbage; will eat mollusks if available	
Green-winged teal	*Anas carolinensis*	omnivore	seeds and invertebrates	
Glaucous-winged gull	*Larus glaucescens*	carnivore	fish and aquatic invertebrates, mollusks, garbage, and carrion	
Lesser scaup	*Aythya affinis*	omnivore	mollusks, crustaceans, aquatic insects, fish eggs, and vegetation	
Ruddy duck	*Oxyura jamaicensis*	omnivore	aquatic insects (e.g., midge larvae), crustaceans mollusks, zooplankton, and other aquatic organisms; diet also may include seeds and aquatic vegetation	Force Lake represents the only breeding and nesting areas within the Portland urban growth boundary (Fishman 1989)
Greater and lesser yellowleg	*Tringa* spp.	carnivore	small fish, crustaceans, snails, and small worms; dietary information not available for lesser yellowleg from Oregon	
Hooded merganser	*Lophodytes cucullatus*	carnivore	small fish, crayfish, aquatic insects, crustaceans, and amphibians	
Common merganser	*Mergus merganser*	carnivore	freshwater and marine fish (prefer < 20 cm), some invertebrates (shrimp, clams, nematodes, fly larvae and adults, sowbugs, centipedes, and beetle larvae); occasionally moss and spruce and hemlock needles	

Table 2-2. Birds Observed on or Near Force Lake

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Bufflehead	*Bucephala albeola*	omnivore	diet varies seasonally; animal matter, especially midge larvae; also consumes water boatmen, snails, seeds, and occasionally fish eggs	
Pied-billed grebe	*Podilyumbus podiceps*	carnivore	fish, crustaceans, dragonfly nymphs, bugs, beetles, amphibians, and other aquatic and terrestrial insects	
Horned grebe	*Podiceps auritus*	carnivore	fish, crayfish, aquatic insects, shrimp, and prawns	
Double-crested cormorant	*Phalacrocorax auritus*	piscivore	fish, few crayfish	
American bittern	*Botaurus lentiginosus*	piscivore	fish, crustaceans, frogs, insects, snakes, and small mammals	
Western gull	*Larus occidentalis*	piscivore	intertidal and pelagic fish, invertebrates, seabirds, bivalves, scavenge from garbage	
Belted kingfisher	*Ceryle alcyon*	piscivore	primarily small fish (< 10 cm) but also crustaceans, insects, amphibians, reptiles, young birds, and small mammals	
Great Blue Heron	*Ardea herodias*	piscivore	feeds primarily on fish but also amphibians, aquatic invertebrates, reptiles, mammals, and birds	heron rookery located west of Study Area; heron observed at Force Lake; nesting areas in cottonwoods; observed on site visit
Great egret	*Ardea alba*	piscivore	small fish; also consume frogs, lizards, snakes, mice, moles, crustaceans, snails, and insects	observed on site visit
Green-backed heron	*Butorides virescens*	piscivore	small fish; also consume invertebrates (e.g., crustaceans, snails) and some terrestrial species such as mice, and snakes	
Red-tailed hawk	*Buteo jamaicensis*	raptor	small to medium-sized rodents; may also eat snakes; likely prey on Eastern cottontails as main food source	nesting areas in cottonwoods about 200 m from Force Lake

Source: City of Portland (1997)

[a] Diet information based on Csuti et al. (2001) and Marshall et al. (2003).

Table 2-3. Birds Observed in Pen 1

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Mourning dove	*Zenaida macroura*	herbivore	grains and seeds	
Purple finch	*Carpodacus purpureus*	herbivore	mainly vegetative matter; occasionally consume insects in summer	
Ringed-neck pheasant	*Phasianus colchicus*	herbivore	green vegetation, fruits, and berries	range throughout Pen 1
Northern pintail duck	*Anas acuta*	herbivore	aquatic plants and seeds; invertebrates during breeding	observed by staff at Heron Lakes Golf Course
California quail	*Callipepla californica*	herbivore	primarily green plant material and seeds, insects, < 1% invertebrates	observed by staff at Heron Lakes Golf Course
Mallard	*Anas platyrhynchos*	herbivore	mostly aquatic plants and seeds; occasionally grain and some invertebrates	winter in various areas, including Force Lake
House sparrow	*Passer domesticus*	herbivore	primarily vegetable matter; some insects during spring and summer	
Tree swallow	*Tachycineta bicolor*	insectivore	primarily insects; berries and seeds when insects are not available	
Bewick's wren	*Thryomanes bewickii*	insectivore	mostly insects (97% of diet) gleaned from branches and leaves	
House wren	*Troglodytes aedon*	insectivore	arthropods from surface of leaves	
Western wood peewee	*Contopus sordidulus*	insectivore	99% insects and spiders; small amount of vegetable matter, included seeds, berries, and fruits	
Killdeer	*Charadrius vociferous*	invertivore	terrestrial and aquatic invertebrates, including flying insects, spiders, worms, beetles, crayfish, and snails	
Marsh wren	*Cistothorus palustris*	invertivore	generalist consumer of invertebrates	
Swainson's thrush	*Catharus ustulatus*	omnivore	invertebrates, fruits, moss, and lichens	
Varied thrush	*Ixoreus naevius*	omnivore	berries, invertebrates, and insects	observed as wintering birds

Table 2-3. Birds Observed in Pen 1

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Northern flicker	*Colaptes auratus*	omnivore	primarily insects (ants, beetles), spiders, and plant matter	
Black-headed grosbeak	*Pheucticus melanocephalus*	omnivore	seeds, insects, beetles, cicadas, weevils, cultivated fruit, butterflies, and moths	
Black-headed cowbird	*Molothrus ater*	omnivore	insects, grasses, seeds, fruits, and berries	
European starling	*Sturnus vulgaris*	omnivore	opportunistic feeders; includes insects, small inverts, earthworms, plant matter; also may scavenge in dumpsters	
Rock dove	*Columba livia*	omnivore	forages for food refuse, handouts from humans, weed seeds, and grain spilled at shipping locations	
Western meadowlark	*Sturnella neglecta*	omnivore	diet varies seasonally; insects, seeds, and grain	observed by staff at Heron Lakes Golf Course
Western tanager	*Piranga ludoviviana*	omnivore	opportunistic feeders; includes wasps, ants, beetles, and wood borers; will consume fruit and berries when available	observed by staff at Heron Lakes Golf Course
Tri-colored blackbird	*Agelaius tricolor*	omnivore	insects, invertebrates, and plant matter	observed at Heron Lakes Golf Course; only known colony in the Willamette Valley near Pen 1; Oregon state sensitive species and federal species of concern
Cattle egret	*Bubulcus ibis*	omnivore	opportunistic feeder; includes grasshoppers, flies, moths, crickets, spiders, frogs, and earthworms	observed by staff at Heron Lakes Golf Course
Brewer's blackbird	*Euphagus cyanoceplalus*	omnivore	insects, plant seeds, cultivated grains; will also forage in garbage	
Yellow-crown blackbird	*Xanthocephelus xanthocephalus*	omnivore	diet varies seasonally; includes insects, grains, and seeds	observed by staff at Heron Lakes Golf Course
Merlin	*Falco columbaris*	carnivore	small to medium-sized birds; also large flying insects such as dragonflies, small mammals, and reptiles	observed by staff at Heron Lakes Golf Course
Common goldeneye	*Bucephala clangula*	carnivore	mainly animal diet, supplemented with plant food	observed by staff at Heron Lakes Golf Course

Table 2-3. Birds Observed in Pen 1

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Common cormorant	*Phalacrocorax carbo*	piscivore	mainly fish; some mollusks and crustaceans	observed by staff at Heron Lakes Golf Course
Osprey	*Pandion halieatus*	piscivore	fish (almost 100% of diet; 4 to12 inches in length); may also eat reptiles, small mammals, birds, and amphibians	observed by staff at Heron Lakes Golf Course
Bald eagle	*Haliaeetus leucocephalus*	raptor	fish, birds, and mammals	observed at Heron Lakes Golf Course and at Portland International Raceway; observed over- wintering in Columbia Boulevard Sewage Treatment Plant; Oregon state endangered species
Peregrine falcons	*Falco peregrinus*	raptor	Birds (e.g., doves, starlings, and sandpipers); may also consume bats, squirrels, lizards, and insects	observed flying overhead at Pen 1
Marsh hawk (Northern harrier)	*Circus cyaneus*	raptor	small and medium-sized mammals (e.g., voles and mice); may also eat birds	observed by staff at Heron Lakes Golf Course
Snow owl	*Nyctea scandica*	raptor	small to medium-sized mammals	observed by staff at Heron Lakes Golf Course
Barn owl	*Tyto alba*	raptor	mammals, mostly field mice and voles; also eats deer mice, cottontails, and small birds	observed by staff at Heron Lakes Golf Course
Great horned owl	*Bubo virginianus*	raptor	small mammals; rabbits, hares, mice, and voles; likely prey on Eastern cottontails as main food source	nesting areas in cottonwoods

Source: City of Portland (1997)

[a] Diet information based on Csuti et al. (2001) and Marshall et al. (2003).

Great blue heron and red-tailed hawk have been observed nesting in areas near Force Lake (City of Portland 1997). Great blue heron, egrets, dabbling ducks, and songbirds were observed during a summer 2007 site visit as part of the RI. American wigeon and mallards are known to winter near Force Lake (City of Portland 1997). Force Lake represents the only breeding and nesting habitat within the Portland urban growth boundary for ruddy ducks, which have been observed at Force Lake (Fishman 1989). A heron rookery is located approximately one-half mile west of the Study Area in the Pen 1 area.

During the April 2009 fish survey, several osprey were observed near Force Lake. Jesse Goodling, the Heron Lakes Golf Course superintendent since 1986, noted that osprey are present in the area each year for several months during the summer. The radius of osprey foraging areas can range from 1 to 10 km (EPA 1993b), and thus the lake is unlikely to be the sole food source for osprey that summer in the region. While the fish survey was being conducted, one osprey was observed catching a fish (likely a carp approximately 10 to 15 cm in length) at Force Lake. A west-central Idaho osprey study reported 89% of fish ingested by osprey were 11 to 30 cm long, suggesting a preference for small-to-medium-sized fish (Van Daele and Van Daele 1982).

Two birds that are special-status species have been observed in Pen 1 (Table 2-3). Tri-colored blackbirds are Oregon State sensitive species and are a federal species of concern. Bald eagles are Oregon listed as endangered and are also protected under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.

2.2.4 Mammals

Several predominately herbivorous mammal species, including Eastern cottontails, voles, beavers, and nutria have been observed near Force Lake based on the City of Portland BOP survey conducted in 1997 (City of Portland 1997). In addition, two opportunistic feeders, raccoon and opossum, have also been observed (City of Portland 1997) (Table 2-4).

Table 2-4. Mammals Observed in Pen 1

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Eastern cottontail	*Sylvilagus floridanus*	herbivore	grasses and other plants	
Vole	*Microtus* spp.	herbivore	varies among species; generally includes plants (e.g., grasses and forbs), seeds, berries, roots, bark, and fungi	
American Beaver	*Castor canadensis*	herbivore	terrestrial plants (especially willow and aspen) and aquatic plants	commonly found in sloughs

Table 2-4. Mammals Observed in Pen 1

Common Name	Scientific Name	Feeding Guild	Diet[a]	Notes
Nutria	*Myocastor coypus*	herbivore	aquatic plants, grasses, fruit, some mollusks	commonly found in sloughs
Raccoon	*Procyon lotor*	omnivore	opportunistic feeders; includes small mammals, fish, frogs, birds, fruit, nuts, and berries	range throughout Pen 1
Opossum	*Didelphis virginiana*	omnivore	opportunistic feeders; includes insects, vertebrates, fruit, grain, and bird eggs	range throughout Pen 1

Source: City of Portland (1997)

[a] Diet information based on Csuti et al. (2001).

Informal wildlife observations have also been made during monthly inspections of the Vanport wetlands (a 90-acre wetland mitigation site located east of Force Avenue opposite the Study Area). The following mammals were observed in 2003: beaver, bat, black-tailed deer, cottontail rabbit, coyote, house cat, mole, nutria, opossum, raccoon, squirrel, and vole (Port of Portland 2004).

Invertivorous rodents, such as shrews, may also be present in the wetland areas near Force Lake. Shrew (*Sorex* species) are found in aquatic habitats in northwestern Oregon, including marshes, and consume a variety of small invertebrates, including beetles, worms, sowbugs, snails, earthworms, centipedes, and some vegetable matter (Csuti et al. 2001). The habitat type at the Study Area is suitable for shrew. Other aquatic mammals that have not been observed but could also use the Study Area or nearby habitat include muskrats, which are omnivorous feeders that consume mostly plants (e.g., aquatic plants, grasses, and fruit), and occasionally aquatic prey such as crayfish, fish, turtles, snails, or salamanders (Csuti et al. 2001).

No special-status mammal species are known to be present at the Study Area or nearby habitat areas.

2.3 Selected Ecological Receptors of Concern

This section presents the ROCs selected to represent terrestrial invertebrates, aquatic benthic invertebrates, fish, and wildlife species based on a set of ROC selection criteria. Selected ROCs were agreed to by EPA as part of their comments on the risk assessment scoping memorandum (Windward and Bridgewater 2008).

Inherent in the ROC selection process was the realization that not all species in the vicinity of the Study Area can be evaluated individually because of the large number and variety of species present. Instead, representative species were chosen to include species that are most likely to be exposed to COPCs within the adjacent wetlands and in Force Lake. This process would ensure that the evaluation would also be protective of species not selected. Individual species selected as ROCs (e.g., brown bullhead, shrew) were selected as representative surrogate species to be protective of their respective feeding guilds (e.g., omnivorous fish, invertivorous mammals).

A systematic process was followed to select representative species for key ecological feeding guilds as ROCs based on the available information for the resources presented in Section 2.2. This process is consistent with EPA guidance (EPA 1997a, 1998) and the process commonly used in Superfund risk assessments.

Key considerations in the selection of ROCs included:

- Potential for direct or indirect (e.g., through ingestion of fish or invertebrates) exposure to chemicals
- Human and ecological significance
- Study Area usage
- Sensitivity to COPCs
- Susceptibility to biomagnification of COPCs (i.e., higher-trophic-level species)

To ensure that selected ROCs represented all potential exposure pathways, key direct and indirect exposure pathways were identified. Groups of organisms that could be exposed via these pathways were then identified, and representative species thought to be most exposed were selected from the groups representing the greatest potential for exposure. Next, human or ecological significance was considered (i.e., species valued by society, having special regulatory status [threatened or endangered], or serving a unique ecological function).

Study Area usage and sensitivity to COPCs were also evaluated. Study Area usage is an important criterion in determining the exposure of a species; consideration was given to species that may use the Study Area during a significant part of the year or during sensitive periods, such as gestation and rearing of young. Sensitivity to COPCs was evaluated based on available toxicological data. The following sections provide the rationale for each of the ROCs selected.

2.3.1 Invertebrates

The aquatic benthic invertebrate community and the wetland invertebrate community were selected as ROCs. Invertebrate species are in direct contact with sediment and soil year-round and have a limited home range. Invertebrates use various techniques to nourish themselves and thus may be exposed to COPCs through several different pathways. Aquatic benthic invertebrates include sediment dwellers (benthic infauna) and organisms closely associated with the sediment surface (epibenthos). Soil invertebrates can also live within the soil (e.g., earthworms) or on the soil surface. Flying invertebrates are also important species in the ecosystem.

Invertebrates are an important food source for other invertebrates, fish, birds, and mammals and perform essential functions, such as nutrient cycling. Thus, the diversity and abundance of invertebrates is an important component of the ecosystem. In addition, invertebrates have been shown to be sensitive to COPCs, and data are available to assess their exposure and predict effects.

2.3.2 Fish

A total of six fish species have been observed in Force Lake (Section 2.2.2). Two feeding guilds were identified: omnivorous fish and insectivorous fish. Brown bullhead and pumpkinseed,[12] representing the two feeding guilds, were selected as the fish ROCs to be evaluated in the ERA (see Table 2-1). The presence of both of these species was confirmed during the fish survey conducted in April 2009. As juveniles, brown bullhead (omnivores) consume primarily invertebrate prey, and adults consume multiple trophic levels, including small fish and macroinvertebrates. Pumpkinseed are primarily invertivorous.

2.3.3 Birds

Over 90 bird species have been observed in or near Force Lake or in adjacent wetland areas (Tables 2-2 and 2-3). Five primary feeding guilds were identified: herbivore, insectivore/invertivore, piscivore, carnivore (raptors), and omnivore. Bird ROCs were selected from three feeding guilds: invertivore, piscivore, and raptor to represent higher-trophic-level birds that may be more exposed to bioaccumulative COPCs. Representative receptor species were not selected from omnivore or herbivore feeding guilds. Birds with omnivorous diets were assumed to be addressed based on the evaluation of other more specific feeding guilds (i.e., their diets would be intermediate between an invertivore and a piscivore). An herbivorous bird ROC was not selected because exposures through plant consumption were assumed to be lower than exposure through the consumption of higher-trophic-level species (e.g., invertebrates or fish) for bioaccumulative chemicals; and therefore, it was assumed that these trophic levels will also be protective of herbivorous birds.

The selected preliminary bird ROCs and the rationale for selection are as follows:

- **Ruddy Duck:** The ruddy duck was selected to represent invertivorous birds, specifically invertebrate-feeding ducks. Force

[12] Mosquitofish were identified as a fish ROC in the RI/FS Work Plan (Bridgewater et al. 2008b) and risk assessment scoping memorandum (Windward and Bridgewater 2008) instead of pumpkinseed. However, pumpkinseed is a more appropriate ROC for this ERA because mosquitofish were not observed during the April 2009 survey and mosquitofish have not been released by the Multnomah County Vector Control to help manage mosquito populations since the mid-1990s.

Lake represents a unique habitat for the ruddy duck, inasmuch as it has been identified as the only breeding and nesting area for ruddy duck within the Portland urban growth boundary (Fishman 1989). Ruddy ducks primarily consume invertebrates, feeding on aquatic insects, crustaceans, mollusks, zooplankton, or other invertebrates (Brua 2002, Marshall et al. 2003). Aquatic insects and aquatic invertebrates have been reported to comprise 73% or more of the ruddy duck's diet (Brua 2002). Ruddy ducks may also consume small amounts of aquatic vegetation and seeds (Brua 2002). In fact, one study indicated that plant material may comprise 75% of their diet, depending on the season (Csuti et al. 2001). However, for this ERA, the diet of the ruddy duck was evaluated as an invertebrate-dominated diet. The ruddy duck was selected over hooded merganser to represent invertebrate-feeding ducks, because the portion of invertebrates in the ruddy duck diet (73% or greater) was estimated to be higher than that of the hooded merganser (50%) or other ducks (e.g., lesser scaup).

- **Great blue heron:** Great blue heron were selected to represent piscivorous birds feeding in Force Lake. Their diet is composed of aquatic prey, including small fish, some amphibians, and invertebrates. Heron use the habitat at Force Lake, have known nesting areas near Force Lake (City of Portland 1997), and were observed in the 2007 site visit. Great blue heron are also of interest because of the rookery located nearby. The great blue heron is also expected to be protective of other piscivorous birds, such as osprey, because great blue heron are expected to have a higher frequency of feeding at Force Lake as a result of the nearby rookery.
- **Red-tailed hawk:** Red tailed hawk were selected as a representative terrestrial raptor. Red-tailed hawk nesting areas have been observed in cottonwood trees near Force Lake (approximately 200 meters from the lake) (City of Portland 1997). Hawk likely feed on small mammals, such as Eastern cottontails or shrew, as their main food source. Red-tailed hawk are expected to have an exposure that is higher than other terrestrial birds (e.g., robin) because of its high trophic level (feeding primarily on small mammals), especially to bioaccumulative chemicals such as DDTs.

The listed species (i.e., tri-colored blackbirds, bald eagles, and peregrine falcons) were not selected as preliminary ROCs because risks to these species were assumed to be similar to or lower than risks to the selected ROCs based on diet and site usage.

2.3.4 Mammals

Six mammalian species have been observed or are suspected to use the habitat within the Study Area (Table 2-4). These species represent omnivorous and herbivorous wetland species. Although shrew have not been observed within the Study Area (Table 2-4) or in the nearby Vanport wetlands (Port of Portland 2004), they represent a small-home-range mammal receptor with an intermediate-trophic-level diet (invertebrates). Thus, shrew was selected as the mammalian ROC.

In general, shrews feed primarily (or exclusively) on invertebrates and, depending on the species, will eat both aquatic insects and/or terrestrial invertebrates (e.g., beetles, worms, snails, sowbugs) (Csuti et al. 2001). Shrews also represent a species with a smaller home range than that of opportunistic feeders such as raccoon and opossum and therefore represent an appropriate species to evaluate risks within the habitat area at the Study Area. The summer home range of a short-tailed shrew is < 0.1 to 1.8 hectares (0.2 to 4.4 acres), with an average year-round home range of 0.39 hectare (approximately 1 acre) (EPA 1993b).

As discussed in Section 2.2, Eastern cottontails, voles, beavers, nutria, raccoons, and opossums have been observed near Force Lake (City of Portland 1997). To better characterize risks to terrestrial mammals known to inhabit the Study Area, Eastern cottontail was selected as a second terrestrial mammal ROC for the Study Area. Eastern cottontail represents an herbivorous terrestrial mammal with a home range generally between 1 and 3 hectares (2.5 to 7 acres) (EPA 1993b; Sample and Suter 1994). Eastern cottontail are known to use a wide variety of habitats and often prefer open grassy areas such as those covering part of the wetland area at the Study Area.

A piscivorous mammal ROC was not selected because there were no observed aquatic mammals that would be strictly piscivorous feeders in the Pen 1 area (Table 2-4). Some opportunistic feeders were observed (including raccoons) in Pen 1, and other omnivorous feeders have also been observed (such as nutria or muskrats). These species may be present at the Study Area and may also consume fish from Force Lake on rare occasion. However, because the diets of these omnivores are varied and the home ranges are variable, these species were not selected.

2.3.5 Summary of ROCs

In summary, risks at the Study Area were evaluated in this baseline ERA for each of the following ecological ROCs:

- **Invertebrates:** aquatic benthic invertebrate community and wetland invertebrate community
- **Fish:** brown bullhead (omnivorous fish) and pumpkinseed (invertivorous fish)
- **Birds:** ruddy duck (invertivorous bird), great blue heron (piscivorous bird), and red-tailed hawk (higher-trophic-level carnivorous bird)
- **Mammals:** shrew (invertivorous mammal) and Eastern cottontail (herbivorous mammal)

2.4 Data Selection, Reduction, and Suitability

This section presents a summary of the data available for the Study Area and discusses its use in the ERA. The following subsections describe data availability (Section 2.4.1), data reduction (Section 2.4.2), and the suitability of data for risk assessment purposes (Section 2.4.3).

2.4.1 Data Availability and Selection

Numerous environmental investigations have been conducted at the Study Area since 1988. This section discusses the various data sources that are available for the Study Area and identifies which of these datasets are appropriate for use in this ERA.

2.4.1.1 Historical Datasets

This section summarizes the methods and results of a data quality screen conducted as part of the data quality objective (DQO) process to determine whether historical data are acceptable for use in the ERA, as presented in the risk assessment scoping memorandum (Windward and Bridgewater 2008). This data quality screen ensured that data used in this ERA were of adequate quality.

Multiple field investigations at the Facility, adjacent wetland areas, and Force Lake have been conducted since 1988 (Table 2-5). Data from these historical studies were considered for use in the ERA dataset if acceptable laboratory methods were used and sufficient analytical and field documentation was available. Data were considered to be unacceptable for use in the ERA dataset if field screening methods were used or if insufficient analytical and field documentation was available. Dataset acceptability was evaluated based on the criteria established in the RI/FS Work Plan (Bridgewater et al. 2008b).

Table 2-5. Datasets Reviewed for Data Quality and Documentation for the Harbor Oil RI

Year	Sampling Event	Data Summary
2001 to 2006	Heron Lakes Golf Course water quality sampling performed by the City of Portland (unpublished)	samples have been collected twice per year since 2001 and analyzed for indicators of nutrient runoff and pesticides (only one year of data was provided to the Voluntary Group)
2003	soil analysis results for the 2003 excavations required for the construction of the EMRI base oil plant (Coles 2007)	19 subsurface soil samples were analyzed for TPH-Dx and PCBs
2000	Harbor Oil preliminary assessment/site inspection (Ecology and Environment 2001)	15 surface soil samples, 10 subsurface soil samples, 6 Force Lake sediment samples, 7 groundwater samples, and 1 LNAPL sample were analyzed for TPH-HCID, TPH-G, TPH-Dx metals, VOCs, SVOCs, PCBs, and pesticides
2000	preliminary risk assessment problem formulation (Coles 2002)	4 surface soil samples, 1 wetland soil sample, and 3 groundwater samples were analyzed for TPH-HCID, TPH-G, TPH-Dx, lead, magnesium, VOCs, SVOCs, and PCBs
1992	Peninsula Drainage District 1 NRMP (City of Portland 1997)	1 Force Lake surface water sample and 1 Force Lake sediment sample were analyzed for TPH (range not reported), metals, VOCs, SVOCs, PCBs, pesticides, and herbicides
1990	Portland Stockyards site investigation and preliminary remediation plan (Golder Associates 1990)	2 surface soil samples, 9 subsurface soil samples, 3 wetland soil samples, and 3 groundwater samples were analyzed for metals
1990	Black & Veatch and RZA Stockyards site assessment (RZA 1990, as cited in Golder Associates 1990)	39 soil vapor samples for VOCs at Merit Truck Stop, Star Oil, Harbor Oil, Rod's Truck Repair, and Stockyards facility; unspecified testing related to underground storage tanks at Merit Truck Stop and the Star Oil facility
1988	Sweet Edwards/Emcon Environmental Audit: Field Investigation and Remedial Alternatives Assessment (Sweet Edwards/Emcon 1988, as cited in Golder Associates 1990)	19 shallow borings, 17 surface soils, and an unspecified number of groundwater samples analyzed for VOCs, PCBs, diesel, and gasoline; samples were collected at Rod's Truck Repair, Harbor Oil, Merit Truck Stop, and Farmers Plant Aid

EMRI – Energy & Material Recovery, Inc.
LNAPL – light non-aqueous phase liquid
NRMP – natural resource management plan
PCB – polychlorinated biphenyl
RI – remedial investigation
RZA – Rittenhouse-Zeman and Associates
SE/E – Sweet-Edwards/EMCON
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
TPH-Dx – total petroleum hydrocarbons – diesel and oil extractable
TPH-G – total petroleum hydrocarbons – gasoline
TPH-HCID – total petroleum hydrocarbons-hydrocarbon identification
VOC – volatile organic compound

Criteria for Historical Data Screen

Specific criteria were used to evaluate chemistry data collected from previous sampling events to determine their acceptability for use in the RI. All new data collected through the RI process outlined in the RI/FS Work Plan meet these criteria through compliance with the methods detailed in the quality assurance project plan (QAPP) (Bridgewater et al. 2008b).

The criteria required for chemistry data use in the RI for all purposes are as follows:

- Hard copy or original electronic copy of data report must be available.
- Field coordinates must be available.
- Data must have been collected using acceptable sampling methods.
- Sample depth must be identified.
- Sample type must be clearly identified.
- Analytical methods must be identified and be acceptable.
- Quality assurance/quality control (QA/QC) information must be available.
- Data validation qualifiers must be present, or derivable from laboratory qualifiers or QA information, and must be applied in a manner consistent with EPA functional guidelines (EPA 1999, 2002c). For non-detected results, detection limits and appropriate qualifiers must be provided.
- Data reports should contain laboratory-generated forms (often called Form Is) with the results for each sample.
- Documentation supporting the dataset, including the analytical raw data, chain-of-custody forms, and sample handling descriptions, should be available for future reference, confirmation, and/or reproducibility by a third party.

Although EPA has no established definitive guidelines specifying the level of data validation required for CERCLA, EPA Order 5360.1 and Office of Solid Waste and Emergency Response (OSWER) Directive 9355.9-01 (EPA 1993a) require environmental measurements to be of known quality, verifiable, and defensible. EPA's information quality guidelines (2002a) require that a historical dataset be of known quality and legally defensible and have undergone the same level of scrutiny and review as any other environmental data generated internally or externally by or for EPA to be used for decision-making.

Historical Data Screen Results

The results of the data screen are presented in Table 2-6. The data from one sampling event (Ecology and Environment 2001) were determined to be acceptable for use in this ERA. Data from seven sampling events did not meet minimum DQOs and were determined to be unsuitable for use in the ERA. These seven sampling events are listed in Table 2-6 with the rationale for their exclusion.

Table 2-6. Results of Data Screen of Historical Datasets

Sampling Year	Sampling Event	Available Documentation	Acceptability for All Uses in the RI	Rationale for Exclusion
2001 to 2006	Heron Lakes Golf Course water quality sampling conducted by the City of Portland 2006, unpublished	laboratory reports provided by J. Goodling to S. Brown	unacceptable	Minimum DQOs were not met; data report and supporting documentation were not available.
2003	soil analysis results for the 2003 excavations required for the construction of the EMRI base oil plant (Coles 2007)	field notes, chain-of-custody forms, and laboratory report forms	unacceptable	Minimum DQOs were not met; data report was not available.
2000	Harbor Oil preliminary assessment/site inspection (Ecology and Environment 2001)	sampling and quality assurance plan, data report, data validation memoranda, laboratory report forms; raw data and chain-of-custody forms are on file with EPA, Ecology and Environment, Inc., and/or MEL	acceptable	Dataset was acceptable.
2000	preliminary risk assessment problem formulation (Coles 2002)	laboratory report forms; some QA/QC information; sampling methods, sample depths, and coordinates not provided	unacceptable	Minimum DQOs were not met; data were unvalidated; raw data were unavailable; uncertainty regarding sampling locations, methods, and depths.
1992	Peninsula Drainage District 1 NRMP (City of Portland 1997)	incomplete data report; copies of laboratory report forms and QA/QC information are not available; sampling methods, locations, and depths not provided	unacceptable	Minimum DQOs were not met; laboratory report forms and QA/QC information were unavailable; uncertainty regarding sampling locations, methods, and depths.
1990	Portland Stockyards site investigation and preliminary remediation plan (Golder Associates 1990)	data report	unacceptable	Minimum DQOs were not met; laboratory report forms and QA/QC information were unavailable.
1990	Black & Veatch and RZA Stockyards site assessment (RZA 1990 as cited in Golder Associates 1990)	incomplete documentation and uncertain data quality	unacceptable	Minimum DQOs were not met; data report and supporting documentation were not available.

Table 2-6. Results of Data Screen of Historical Datasets

Sampling Year	Sampling Event	Available Documentation	Acceptability for All Uses in the RI	Rationale for Exclusion
1988	Sweet Edwards/Emcon Environmental Audit: Field Investigation and Remedial Alternatives Assessment (Sweet Edwards/Emcon 1988 as cited in Golder Associates 1990)	incomplete documentation and uncertain data quality	unacceptable	Minimum DQOs were not met; data report and supporting documentation were not available.

DQO – data quality objective
EMRI – Energy & Material Recovery, Inc.
MEL – Manchester Environmental Laboratory
NRMP – natural resource management plan
PCB – polychlorinated biphenyl
QA/QC – quality assurance/quality control
RI – remedial investigation
RZA – Rittenhouse-Zeman and Associates
SE/E – Sweet-Edwards/EMCON
TPH – total petroleum hydrocarbons

2.4.1.2 Data Acceptable for Use in the Baseline ERA

As described in Section 2.4.1.1, only one of the eight historical datasets available for the Study Area was determined to be acceptable for use in this ERA. In addition to this historical sampling event, two phases of RI data collection have also been conducted at the Study Area (the first in April 2008 and the second in April 2009). Table 2-7 presents a summary of the chemistry data available from these three sampling events.

Table 2-7. Summary of Available Data Used in the Baseline ERA

Sampling Event	Year	Media	Number of Locations	Source	Analyte list
Preliminary Assessment/ Study Area Inspection	2000	groundwater	7	Ecology and Environment (2001)	metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum
		wetland soil	5[a]		metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum, conventionals
RI Phase 1 Sampling	2008	groundwater	16	Windward et al. (2008a)	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		wetland soil	33		metals, PAHs, phthalates, other SVOCs, PCBs, pesticides, VOCs, petroleum, conventionals
		soil berm	9		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		lake sediment	11		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, grain size, conventionals
		lake surface water	3		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum
RI Phase 2 Sampling	2009	wetland soil	13	Harbor Oil RI database	metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, petroleum, conventionals
		groundwater	11		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals
		lake sediment	3		metals, PAHs, SVOCs (excluding phthalates), PCBs, pesticides, VOCs, petroleum, conventionals

[a] A total of six wetland soil samples were collected during this event, but one of these samples was collected on the south side of Force Lake as a background sample. This sample was excluded from the ERA database.

ERA – ecological risk assessment

RI – remedial investigation

PAH – polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

SVOC – semivolatile organic compound

VOC – volatile organic compound

Details on all of the specific samples used in the ERA (across all three sampling events listed above) are summarized in Table 2-8. Figure 2-1 presents the sampling locations for all data evaluated in the ERA.

Table 2-8. Summary of Data Used in the Baseline ERA

Media	Sample Description	Sample Depth	No. of Samples
Wetland soil	berm soil	6 – 24 inches	9
	wetland ditch soil	0 – 6 inches	5
		6 – 12 inches	3
	wetland soil	0 – 6 inches	47
		6 – 12 inches	7
Surface sediment	Force Lake	0 – 4 inches	11
Surface water	Force Lake	0 – 12 inches	3
Groundwater	samples closest to Force Lake	up to 20 ft[a]	10

[a] Groundwater data were evaluated only as part of the uncertainty analysis (Section 5.1.1). For this evaluation, only shallow groundwater samples were used.

ERA – ecological risk assessment

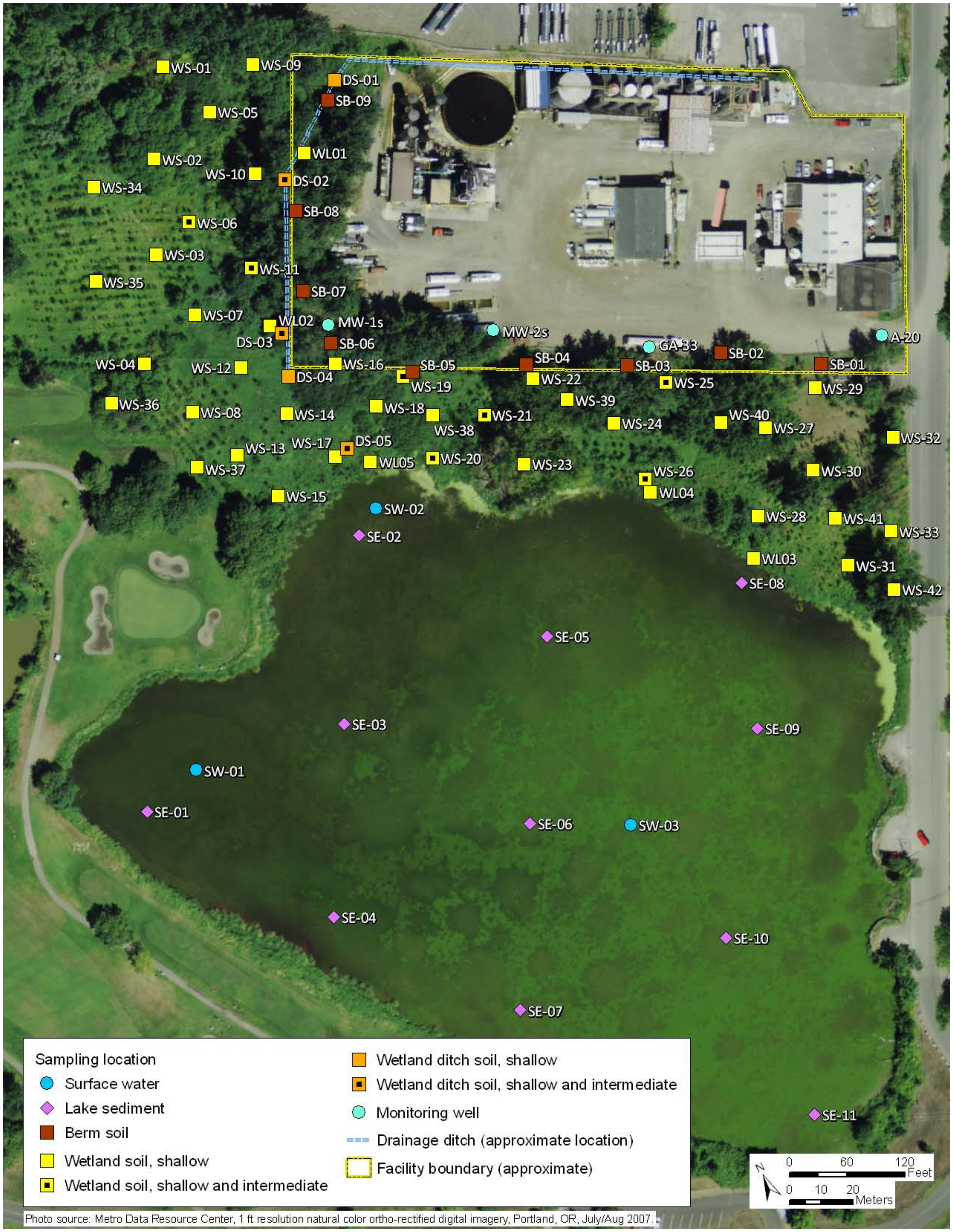


Figure 2-1. Sampling Locations for Data Used in the Baseline ERA

2.4.2 Data Reduction

Data reduction refers to computational methods used to aggregate the data that were selected. The most significant use of aggregated data was for the calculation of exposure point concentrations (EPCs), which are intended to represent estimates of exposure over the appropriate spatial scale for each ROC. The methods used to calculate EPCs are described in detail in the exposure assessment (Section 3.0).

Additional procedures related to averaging, selection of the best data points when multiple data are available, selection of significant figures and rounding procedures, and calculating totals for chemical groupings (i.e., polychlorinated biphenyls [PCBs], polycyclic aromatic hydrocarbons [PAHs], dichlorodiphenyltrichloroethane [DDT], chlordane, and total petroleum hydrocarbons [TPH]) are described below.

2.4.2.1 Duplicate or Replicate Samples

Chemical concentrations obtained from the analysis of laboratory duplicate and triplicate samples (two or more analyses of the same sample) were compared to the results of the original sample. A single value that represented the original sample and laboratory duplicate and triplicate samples was selected. This final result could be verified by comparing the result with the original laboratory reports (i.e., Form Is). Final result selection rules were dependent on whether the individual results were detected. If all concentrations were detected for a single analyte, the maximum detected concentration was selected as the final result. If all results for a given parameter were not detected, the minimum reporting limit (RL) was selected for the final result. If the concentrations were a mixture of detected and non-detected results, the maximum detected concentration was selected as the final result regardless of whether the RLs were higher or lower than the detected concentration.

For grain size, total organic carbon (TOC), and total solids results, the result from the original sample was selected as the final reported result.

2.4.2.2 Selection of Best Results

In some instances, the laboratory generated more than one result for an analyte for a given sample. Multiple results could have occurred for several reasons, including: 1) the original result did not meet the laboratory's internal quality control (QC) guidelines and a reanalysis was performed; 2) the original result did not meet other project data quality indicators, such as a sufficiently low RL, and a reanalysis was performed; or 3) a given parameter is analyzed by more than one method for a given sample. In each case, a single best result was selected for use. If the results were:

- Detected and not qualified, then the result from the lowest dilution was selected, unless multiple results from the same dilution were available, in which case, the result with the highest concentration was selected.

- A combination of estimated and unqualified detected results, then the unqualified result was generally selected. This situation most commonly occurred when the original result was outside of calibration range, thus requiring a dilution.
- All estimated, then the "best result" was selected using best professional judgment in consideration of the rationale for qualification. For example, a result qualified based on laboratory duplicate results outside of QC objectives for precision would be preferred to a qualified result that was outside the calibration range.
- A combination of detected and undetected results, then the detected result was selected. If there was more than one detected result, the applicable rules for multiple results (as discussed above) were followed.
- All undetected results, then the lowest RL was selected.

2.4.2.3 Significant Figures and Rounding

Analytical laboratories reported results with various numbers of significant figures depending on the laboratory's standard operating procedures (SOPs), the instrument, analyte, and the reported concentration relative to the RL. The reported (or assessed) precision of each result was explicitly stored in the project database by recording the number of significant figures. Tracking of significant figures is important when calculating averages and performing other data summaries. When a calculation involved addition, such as totaling PCBs, the calculation could only be as precise as the least precise number that went into the calculation. For example:

> 210 + 19 = 229 would be reported as 230 because although 19 is reported to 2 significant digits, and the trailing zero in the number 210 is not significant

When a calculation involved multiplication or division, the final result was rounded at the end of the calculation to reflect the value used in the calculation with the fewest significant figures. For example:

> 59.9 × 1.2 = 71.88 would be reported as 72 because there are two significant figures in the number 1.2

When rounding, if the number following the last significant figure was less than 5, the digit was left unchanged. If the number following the last significant figure was equal to or greater than 5, the digit was increased by 1. All calculated means and medians were reported to two significant figures.

2.4.2.4 Calculating Totals

Total PCBs, total DDTs, total PAHs, total chlordane, and total TPH were calculated by summing the detected values for the individual components available for each sample. For individual samples in which none of the individual components was detected, the total value was given a value equal to the highest RL[13] of an individual component, and assigned the same qualifier (U or UJ), indicating an undetected result. For individual samples that had both detected and undetected results for the individual components, only the detected concentrations were summed, and the RLs for the undetected components were ignored. Concentrations for the analyte sums were calculated as follows:

- **Total PCBs** were calculated using only detected values for seven Aroclor mixtures.[14] For individual samples in which none of the seven Aroclor mixtures were detected, total PCBs were reported as equal to the highest RL of the seven Aroclors and assigned a U-qualifier. Some regulatory criteria are intended for PCB mixtures of similar toxicity (e.g., lower-toxicity Aroclors 1016, 1221, 1232 and higher-toxicity Aroclors 1242, 1248, 1254, and 1260). Separate total PCB concentrations were calculated if Aroclors of differing toxicity levels were detected in any sample that was compared with regulatory criteria.
- **Total low-molecular-weight PAHs (LPAHs), high-molecular-weight PAHs (HPAHs), PAHs, and benzofluoranthenes** were also calculated during data reduction steps. Total LPAHs were calculated as the sum of detected concentrations of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. Total HPAHs were calculated as the sum of detected concentrations of fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. Total benzofluoranthenes were calculated as the sum of the b (i.e., benzo(b)fluoranthene), j, and k isomers. Because the j isomer is rarely quantified, this sum is typically calculated with only the b and k isomers. For samples in which all individual compounds within any of the three groups described above were undetected, the single highest RL for that sample represented the sum.
- **Total DDTs** were calculated using only detected values for the DDT isomers: 2,4′-dichlorodiphenyldichloroethane (DDD); 4,4′-DDD; 2,4′-dichlorodiphenyldichloroethylene (DDE); 4,4′-DDE; 2,4′-DDT; and 4,4′-DDT. For individual samples in which none of the isomers were detected, total DDTs were given a value equal to the highest RL of the isomers and assigned a U-qualifier, indicating the lack of detected concentrations.
- **Total chlordane** was calculated using only detected values for the following compounds: alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor. For individual samples in which none of these compounds were detected, total

[13] It should be noted that the treatment of RLs in calculating totals is different than the treatment of RLs for duplicate or replicate samples (Section 2.4.2.1) or in the selection of best results (Section 2.4.2.2). The highest RL was used in calculated totals to be conservative; whereas the lowest RL was used in data reduction in order to select the most precise analytical RL reported.
[14] Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

chlordane was given a value equal to the highest RL of the compounds listed above and assigned a U-qualifier, indicating the lack of detected concentrations.

- **Total TPH** was calculated as the sum of the detected concentrations of the diesel, motor oil, and gasoline fractions. For individual samples in which none of these fractions were detected, total TPH was given a value equal to the highest RL of the individual fractions and assigned a U-qualifier, indicating the lack of detected concentrations.

2.4.3 Suitability of Data for Risk Assessment

There are several factors to consider in assessing the suitability of environmental data for risk assessments (EPA 1989, 1992). Of primary importance is the degree to which the data adequately represent site-related contamination and the expected exposures at the site. The data quality criteria goals and the source, documentation, analytical methods, RLs, and level of review associated with the data are also important considerations. Because data from many different investigations were available for the Harbor Oil Study Area, these factors were evaluated for each dataset to determine whether it was reasonable to combine all data for use in this baseline ERA.

2.4.3.1 Representativeness to site-related contamination

The majority of data available for use in this ERA was collected during the two phases of the RI sampling. Because the sampling plan was designed with the risk assessments in mind, the distribution of samples across the site reflects the chemical concentrations at the Study Area based on grid sampling to provide spatial coverage and characterization of Study Area features (such as drainage ditches). For example, the density of wetland soil is quite high, reflecting the higher variability in chemical concentrations in these areas. The density of lake sediment and surface water samples is lower, reflecting the more homogeneous nature of the chemical concentration in Force Lake.

Groundwater samples were collected in summer 2000, spring 2008, and spring 2009 to provide temporal variability information.

It should also be noted that surface sediment samples were collected from North Lake but are not included in this ERA. These samples were collected to determine the extent of chemical migration from Force Lake to North Lake. As presented in the preliminary site characterization report (Windward et al. 2008a, Section 6.5.2), an analysis of these samples indicated that the migration of chemicals from Force Lake to North Lake is limited. Thus, the samples collected from North Lake are not representative of concentrations related to the Facility and are not included in the ERA. The inclusion of these samples in the lake exposure dataset would have reduced exposure concentrations because chemical concentrations are lower in North Lake than in Force Lake.

2.4.3.2 Representativeness to receptor exposure

Ecological receptors may come in contact with chemicals at the Study Area via direct contact or incidental/direct ingestion in Study Area wetlands and Force Lake. A more detailed description of these exposure pathways is presented in Section 2.5.

Invertebrates generally have low mobility and thus will be exposed to soils and sediments in their immediate vicinity. Fish and wildlife receptors will integrate their exposure throughout their home range. If the habitat value is variable within these home ranges, receptors could have differential exposures. However, because the Study Area is small and has relatively homogeneous habitat within the wetland areas and within Force Lake, average concentrations across the Study Area are likely to approximate their exposures.

In addition, the use of both surface (0 to 6 inches) and intermediate (6 to 12 inches[15]) subsurface soil samples allows for a more complete characterization of risks for terrestrial ecological receptors that may come in contact with deeper material.

Groundwater samples that were selected for use in the ERA uncertainty analysis were located at the south end of the facility. These samples were used in the ERA to investigate potential worst-case exposure conditions for aquatic benthic invertebrate and fish risk through groundwater discharge into Force Lake; however, the use of these samples may overestimate exposure because there could be additional attenuation prior to discharge into the lake as a result of the distance of these samples from Force Lake (see Section 5).

2.4.3.3 Quality assurance/quality control and documentation

Documenting field and laboratory procedures allows for the assessment of data usability. In order for data to be considered for use in this ERA, information regarding the sampling method, sample depth, sample type, and sampling location must be available, as discussed in Section 2.4.1.1, to ensure that data are aggregated and interpreted appropriately. Data collected as part of the RI followed field and laboratory procedures that were approved by EPA and met the criteria outlined in Section 2.4.1.1.

The level of analytical data review can also affect data usability. All data used in this ERA were subjected to a thorough data reduction and validation process. All datasets considered suitable for use in this ERA had sufficient documentation to complete this review. Data qualified as unusable by data validators were not used in the ERA.

Analytical methods selected for use in analyzing the samples collected during the two phases of the RI sampling effort were approved by EPA in advance of sampling. For the samples collected as part of the RI sampling effort, the analytical methods are described in the QAPP (Bridgewater et al. 2008a) and were summarized in the preliminary study area characterization report (Windward et al. 2008a). For samples collected as part of the Harbor Oil preliminary assessment/site inspection (Ecology and

[15] Berm soil samples include soil collected from the depth interval from 6 to 24 inches.

Environment 2001), the methods were adequately described in the sampling documentation to determine that they were acceptable.

2.5 Conceptual Study Area Model

A CSM is a graphical representation of chemical sources, transport mechanisms, exposure pathways, and potentially exposed receptors. This section presents the CSM that synthesizes ROC pathways of exposure to chemical stressors. Based on this model and the assessment endpoints for this risk assessment, measures of exposure and effect were selected. These assessment endpoints are examined in detail in this ERA for each ROC-COPC combination that was retained for further analysis based on COPC screen presented in Section 2.6.

2.5.1 Potential Exposure Pathways

For COPCs to pose a risk to ROCs, the exposure pathway must be complete. Identifying complete exposure pathways prior to a quantitative evaluation allows the assessment to focus on only those chemicals that can reach ecological receptors and thus potentially cause adverse effects (EPA 1997a, b). An exposure pathway is considered complete if a chemical can travel from a source to an ecological receptor and the receptor is exposed via one or more exposure pathways (EPA 1997a, b). Complete pathways can be of varying importance, so key pathways that reflect the maximum exposure of an ecological receptor to a specific chemical (EPA 1997a, b) are identified as having more importance than pathways likely to provide a very low fraction of the total exposure of an ROC to a chemical.

Pathways for the exposure of ROCs to chemicals were designated in one of four ways: complete and significant, complete and significance unknown, complete and insignificant, or incomplete. Each of the four designations is defined below. The CSMs for terrestrial and aquatic ecological ROCs are presented in Figures 2-2 and 2-3, respectively.

- **Complete and significant:** There is a direct link between the ROC and chemical via this pathway, and the specific pathway is considered to be potentially important.
- **Complete and significance unknown:** There is a direct link between the ROC and the chemical via this pathway; however, there is insufficient data available to quantify the significance of the pathway in the overall assessment of exposure.
- **Complete and insignificant:** There is a direct link between the ROC and the chemical via this pathway; however, the significance of this pathway in terms of overall exposure is considered to be very low.
- **Incomplete:** There is no direct pathway between the ROC and the chemical.

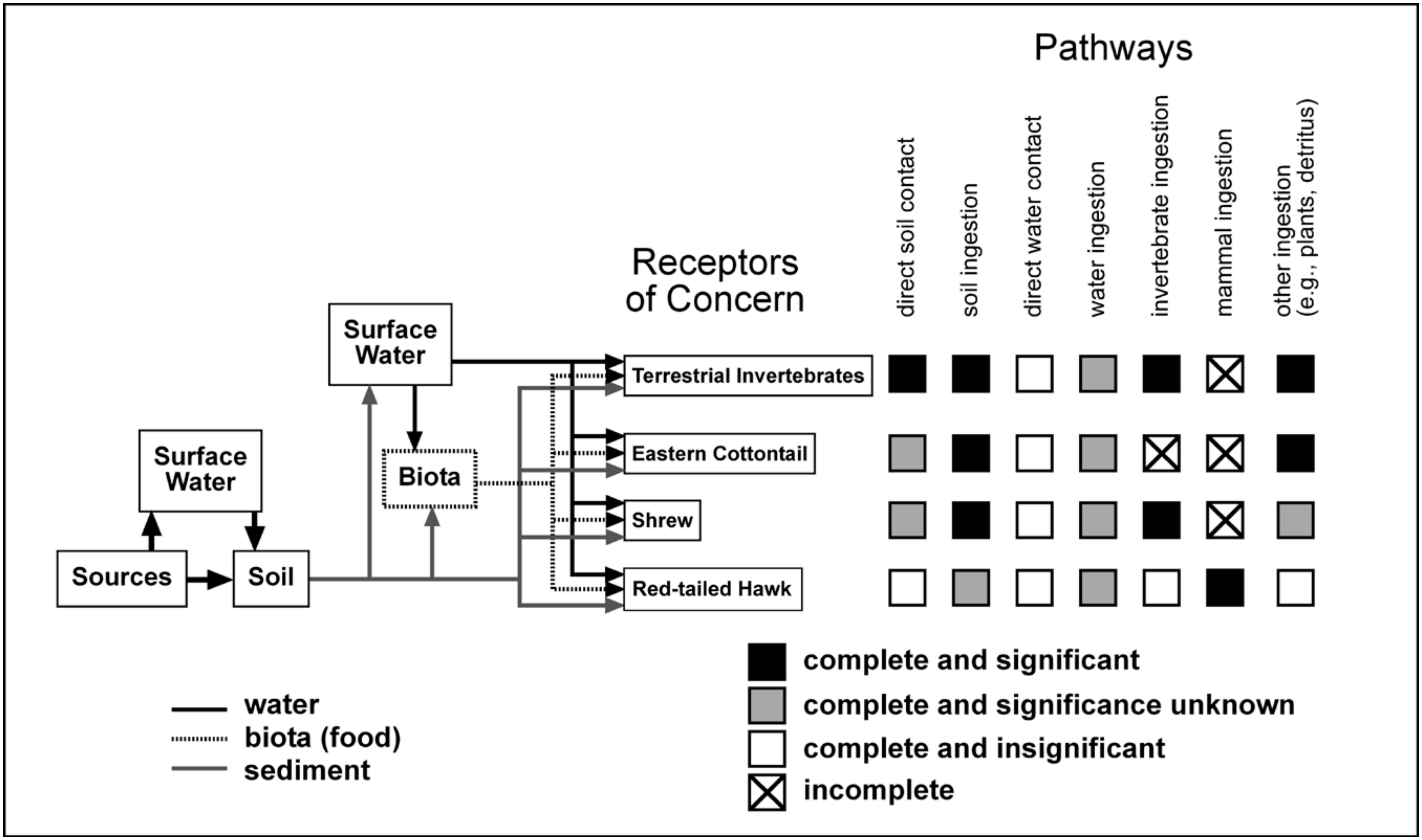


Figure 2-2. Ecological CSM – Terrestrial Receptors of Concern

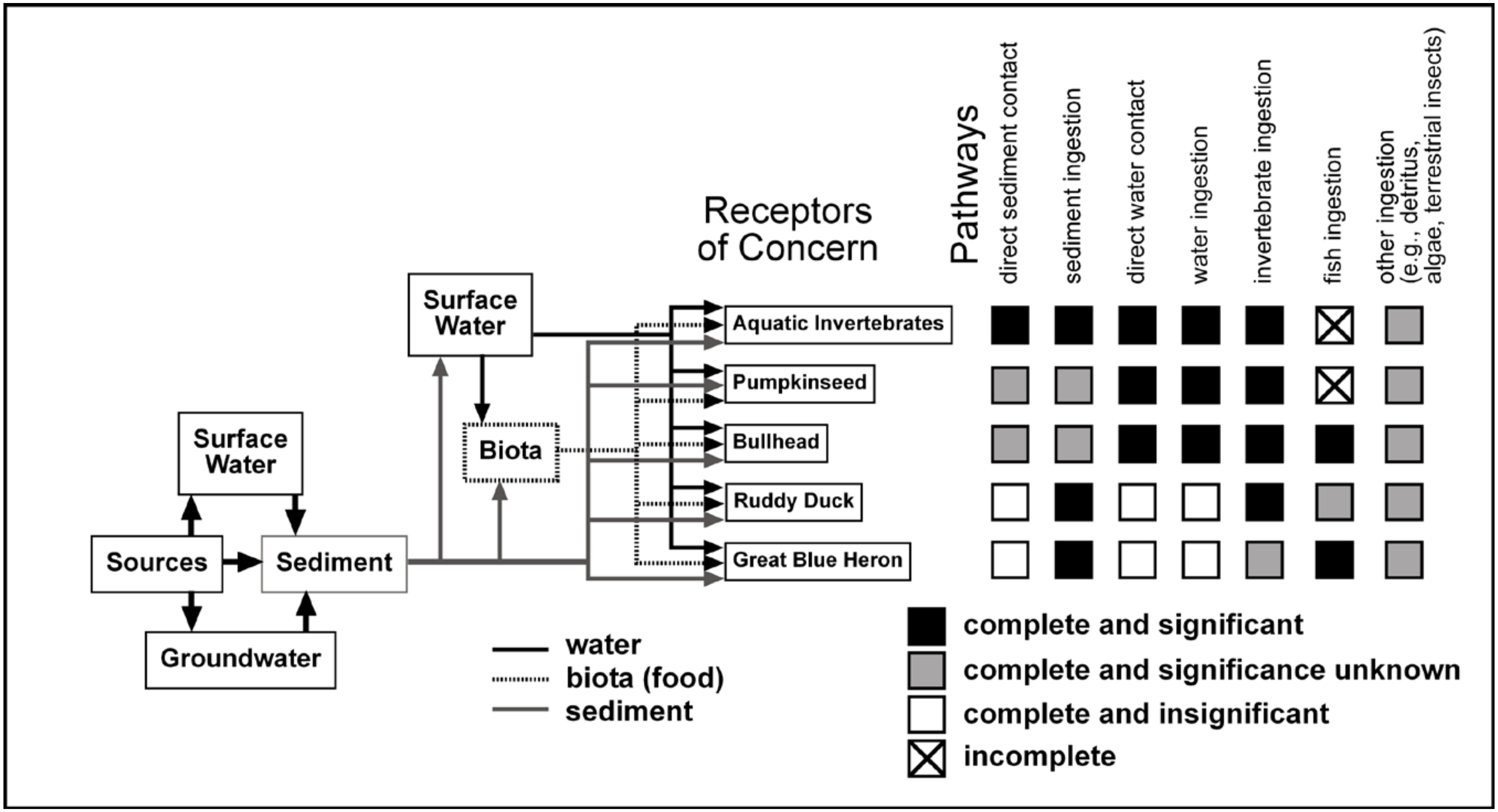


Figure 2-3. Ecological CSM – Aquatic Receptors of Concern

Table 2-9 presents the key exposure pathways for the identified Study Area ecological ROCs that will be further evaluated in this ERA. These are the pathways expected to represent complete and significant exposure pathways, although the significance of some of these pathways is unknown.

Table 2-9. Summary of Complete and Significant Ecological Pathways for the Study Area

Receptor Group	Exposure Route	Ecological Significance
Aquatic benthic invertebrate community	direct contact and ingestion of Force Lake sediments and surface water, diet (ingestion of biota)[a]	food source for other invertebrates, fish, birds, and mammals, aquatic nutrient cycling
Terrestrial invertebrate community	direct contact and ingestion of wetland soils, diet (ingestion of biota)[a]	food source for other invertebrates, birds, and mammals, terrestrial nutrient cycling
Fish (pumpkinseed and brown bullhead)	direct contact and ingestion of Force Lake sediments and surface water, diet (ingestion of biota)	prey item for other fish, birds, and mammals, intermediate trophic level in aquatic food chain
Aquatic birds (ruddy duck and great blue heron)	direct contact and ingestion of Force Lake sediments and surface water, diet (ingestion of biota)	prey item for other birds, intermediate to high trophic level in aquatic food chain
Terrestrial/wetland birds (red-tailed hawk)	direct contact and ingestion of wetland soils, diet (ingestion of biota)	prey item for other birds, high trophic level in terrestrial food chain
Mammals (shrew and Eastern cottontail)	direct contact and ingestion of wetland soils, diet (ingestion of biota), limited direct contact and ingestion of Force Lake sediments and surface water	prey item for birds, intermediate to high trophic level in wetland food chain

Note: The significance of some of these pathways is unknown.

[a] Ingestion of biota for invertebrates was not quantitatively evaluated in this ERA because of insufficient information regarding this exposure route but is considered a complete and significant pathway.

2.5.2 Assessment Endpoints, Risk Hypotheses, and Measurement Endpoints

EPA (1998) defines assessment endpoints as “explicit expressions of the actual environmental value that is to be protected, operationally defined by an ecological entity and its attributes.” Accordingly, assessment endpoints should include both the ecological receptor group or species and characteristic of the ecological function to be protected. According to EPA (1997a), the selection of assessment endpoints depends on:

- Chemicals present and their concentrations
- Chemicals’ mechanisms of toxicity to different groups of organisms

- Ecologically relevant receptor groups that are potentially sensitive or highly exposed to the chemical and the attributes of their natural history
- Potentially complete exposure pathways

The selection of assessment endpoints was based on available information regarding the ecological relevance of the endpoint and on societal values. In addition, assessment endpoints were evaluated to ensure that their protection would likely result in the protection of other valued entities within the system. Survival, growth, and reproduction are the key endpoints for all ROCs in this assessment.

Following the selection of assessment endpoints, a testable hypothesis was developed to determine whether or not a risk to the assessment endpoint exists (EPA 1997a). A testable hypothesis is an operational statement of a research assumption made in order to evaluate logical or empirical consequences (EPA 1998, 1997a). The testable hypotheses are presented as a series of risk questions about the relationship between each of the assessment endpoints and the responses of the receptors when exposed to chemicals from the Study Area.

The general risk question, "Are COPC concentrations in various exposure media (i.e., sediment, surface water, tissue) from the Study Area at levels that might cause adverse effects on the survival, growth, and/or reproduction of the receptors of concern?" was used to prepare a series of testable hypotheses that apply to the assessment endpoints. Hypotheses usually postulate that there is no effect or no difference (among groups or measurements), and data are collected to confirm or refute that hypothesis.

Table 2-10 presents an overview of the proposed assessment endpoints, hypotheses (phrased as questions), representative ROCs, measurement endpoints, and data that were used in the ERA to address the questions.

Table 2-10. Assessment Endpoints for ROCs and Measures of Effect and Exposure

Assessment Endpoint by ROC	Testable Risk Question	Description of Measurement Endpoint	Data to be Evaluated from the Study Area
Invertebrates			
Protection and maintenance (i.e., survival, growth, and reproduction) of the aquatic benthic invertebrate community	Are COPC concentrations in Force Lake surface sediment at levels that might cause an adverse effect on survival, growth, and/or reproduction of the Force Lake benthic invertebrate community?	concentrations in sediment compared to sediment thresholds from the literature that are protective of aquatic benthic invertebrates	concentrations in Force Lake surface sediment samples
	Are COPC concentrations in surface water from Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of the Force Lake aquatic benthic invertebrate community?	concentrations in surface water compared to water thresholds from the literature that are protective of aquatic benthic invertebrates	concentrations in Force Lake surface water samples
	Are COPC concentrations in shallow groundwater samples nearest to Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of the Force Lake benthic invertebrate community?	concentrations in groundwater compared to water thresholds from the literature that are protective of aquatic benthic invertebrates	concentrations in shallow groundwater well samples closest to Force Lake[a]
Protection and maintenance (i.e., survival, growth, and reproduction) of the terrestrial invertebrate community	Are COPC concentrations in wetland soils at levels that might cause an adverse effect on survival, growth, and/or reproduction of the terrestrial invertebrate community present at the Study Area wetlands?	concentrations in wetland soil compared to soil thresholds from the literature that are protective of terrestrial invertebrates	concentrations in wetland, ditch, and berm soil samples

Table 2-10. Assessment Endpoints for ROCs and Measures of Effect and Exposure

Assessment Endpoint by ROC	Testable Risk Question	Description of Measurement Endpoint	Data to be Evaluated from the Study Area
Fish			
Protection and maintenance (i.e., survival, growth, and reproduction) of fish (i.e., pumpkinseed and brown bullhead)	Are estimated COPC concentrations in fish tissue at levels that might cause an adverse effect on survival, growth, and/or reproduction of populations of fish that use Force Lake?	ROC-specific estimated concentrations in fish tissue compared to literature-based tissue-residue TRVs	estimated concentrations in brown bullhead and pumpkinseed
	Are modeled dietary exposures to COPCs from Force Lake prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of fish populations that use Force Lake?	ROC-specific modeled daily doses (estimated from surface sediment and invertebrate and/or fish tissue chemistry) compared to literature-based dietary-dose TRVs	estimated concentrations in aquatic benthic invertebrates and/or fish and concentrations in surface sediment
	Are COPC concentrations in surface water from Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of fish populations that use Force Lake?	concentrations in surface water compared to water thresholds from the literature that are protective of fish	concentrations in Force Lake surface water samples
	Are COPC concentrations in shallow groundwater samples nearest to Force Lake at levels that might cause an adverse effect on survival, growth, and/or reproduction of fish populations that use Force Lake?	concentrations in groundwater compared to water thresholds from the literature that are protective of fish	concentrations in shallow groundwater well samples closest to Force Lake[a]
Birds			
Protection and maintenance (i.e., survival, growth, and reproduction) of terrestrial (i.e., red-tailed hawk) and aquatic birds (i.e., great blue heron and ruddy duck) populations	Are modeled dietary doses of COPCs based on Force Lake sediment and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of ruddy duck populations that use Force Lake?	ROC-specific modeled daily doses (estimated from surface sediment and invertebrate tissue chemistry) compared to literature-based dietary-dose TRVs	estimated concentrations in aquatic benthic invertebrates and concentrations in Force Lake surface sediment
	Are modeled dietary doses of COPCs based on Force Lake sediment and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of great blue heron populations that use Force Lake?	ROC-specific modeled daily doses (estimated from surface sediment and invertebrate and fish tissue chemistry) compared to literature-based dietary-dose TRVs	estimated concentrations in aquatic benthic invertebrates and fish and concentrations in Force Lake surface sediment
	Are modeled dietary doses of COPCs based on wetland soils and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of red-tailed hawk populations that use Study Area wetlands?	ROC-specific modeled daily doses (estimated from wetland soil and mammal tissue chemistry) compared to literature-based dietary-dose TRVs	estimated concentrations in terrestrial small mammals and concentrations in wetland, ditch, and berm soil samples

Table 2-10. Assessment Endpoints for ROCs and Measures of Effect and Exposure

Assessment Endpoint by ROC	Testable Risk Question	Description of Measurement Endpoint	Data to be Evaluated from the Study Area
Mammals			
Protection and maintenance (i.e., survival, growth, and reproduction) of terrestrial mammal (i.e., shrew and Eastern cottontail) populations	Are modeled dietary doses of COPCs based on Force Lake sediment, wetland soil, and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of shrew populations that use Study Area wetlands and Force Lake?	ROC-specific modeled daily doses (estimated from wetland soil, sediment, and aquatic benthic invertebrate and terrestrial invertebrate tissue chemistry) compared to literature-based dietary-dose TRVs	estimated concentrations in aquatic and terrestrial invertebrates and concentrations in Force Lake sediment and wetland, ditch, and berm soil samples
	Are modeled dietary doses of COPCs based on wetland soils and biota prey at levels that might cause an adverse effect on survival, growth, and/or reproduction of Eastern cottontail populations that use Study Area wetlands?	ROC-specific modeled daily doses (estimated from wetland soil and plant tissue chemistry) compared to literature-based dietary-dose TRVs	estimated concentrations in terrestrial plants and concentrations in wetland, ditch, and berm soil samples

[a] Based on the hydrogeology of the Study Area, only shallow groundwater is likely to recharge Force Lake. Thus, the shallow groundwater well samples closest to Force Lake (i.e., MW-1s, MW-2s, GA-33, and A-20 [see Figure 2-1]) were evaluated as part of the uncertainty analysis (Section 5.1.1).

AWQC – ambient water quality criteria
ROC – receptor of concern
TRV – toxicity reference value
COPC – contaminant of potential concern

2.6 COPC Screen

This section presents a risk-based screen that was conducted to identify a list of COPCs for each ROC. A refined list of COPCs is presented in Section 2.7; COPCs not eliminated as part of the refined COPC screen (Section 2.7) are further assessed in the ERA. The COPC screen was conducted in accordance with the methods outlined in the RI/FS Work Plan (Bridgewater et al. 2008b) and risk assessment scoping memorandum (Windward and Bridgewater 2008). The refined COPC screen was conducted in accordance with EPA guidance (EPA 1997a, 2001) to further refine the list of COPCs identified in the screening step and thus streamline the site-specific baseline ERA. This refined screen improves the clarity and transparency of the assessment.

COPCs were determined separately for aquatic benthic invertebrates, terrestrial invertebrates, fish ROCs, bird ROCs, and mammal ROCs, as discussed below.

2.6.1 Aquatic Benthic Invertebrates

This section presents the COPC screen for aquatic benthic invertebrates, which is summarized in Figure 2-4.

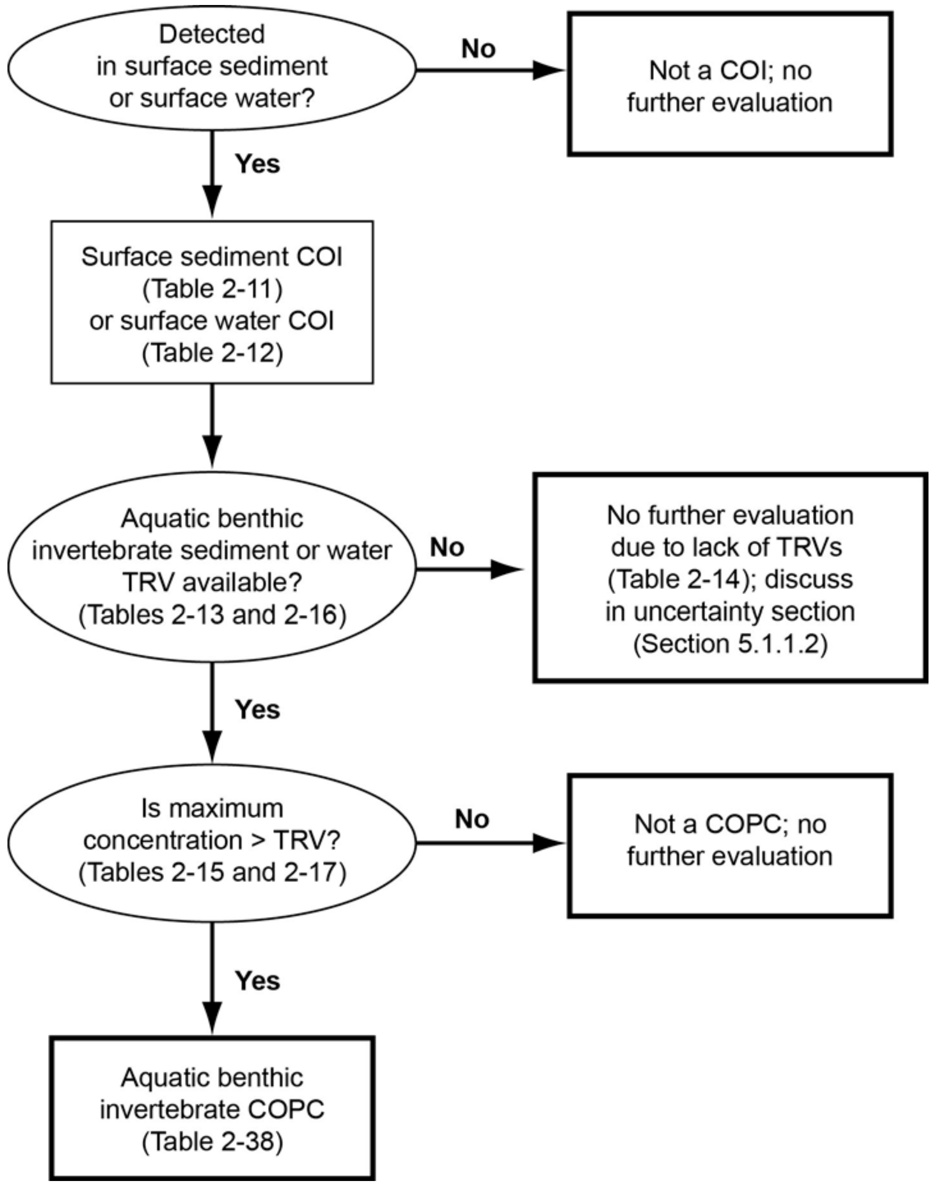


Figure 2-4. COPC Screening Process for Aquatic Benthic Invertebrates

2.6.1.1 COIs for Aquatic Benthic Invertebrates

The first step of the COPC screening process for aquatic benthic invertebrates was to generate a list of contaminants of interest (COIs). Surface sediment and surface water COIs for aquatic benthic invertebrates were defined as any analyte detected in at least one sample in a given media (e.g., an analyte detected in sediment was a sediment COI).

Tables 2-11 and 2-12 present the surface sediment and surface water COIs. These COIs are screened in Sections 2.6.1.2 and 2.6.1.3 to identify COPCs for aquatic benthic invertebrates.

Table 2-11. Chemicals Detected in Surface Sediment and Thus Identified as COIs

Surface Sediment COI	
Metals	
Arsenic	Lead
Barium	Mercury
Cadmium	Nickel
Chromium	Vanadium
Cobalt	Zinc
Copper	
PAHs	
2-Methylnaphthalene	Dibenzo(a,h)anthracene
Acenaphthene	Dibenzofuran
Acenaphthylene	Fluoranthene
Anthracene	Fluorene
Benzo(a)anthracene	Indeno(1,2,3-cd)pyrene
Benzo(a)pyrene	Naphthalene
Benzo(b)fluoranthene	Phenanthrene
Benzo(g,h,i)perylene	Pyrene
Benzo(k)fluoranthene	Total HPAHs
Total benzofluoranthenes	Total LPAHs
Chrysene	Total PAHs
PCBs	
Aroclor 1254	Total PCBs
Aroclor 1260	
Pesticides	
2,4′-DDD	4,4′-DDE
4,4′-DDD	Total DDTs
VOCs	
Acetone	Methyl ethyl ketone
Carbon disulfide	Toluene
TPH	
TPH-gasoline range	TPH-motor oil range
TPH-diesel range	Total petroleum hydrocarbons

COI – contaminant of interest
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 2-12. Chemicals Detected in Surface Water and Thus Identified as COIs

Surface Water COI	
Metals	
Arsenic	Copper
Barium	
VOCs	
Acetone	

COI – contaminant of interest
VOC – volatile organic compound

2.6.1.2 Surface Sediment COPC Screen for Aquatic Benthic Invertebrates

In the second step, COPCs for aquatic benthic invertebrates in surface sediment were identified by comparing maximum detected COI concentrations in surface sediment to aquatic benthic invertebrate-specific sediment screening thresholds. COIs with maximum detected concentrations greater than screening thresholds were considered COPCs for aquatic benthic invertebrates. Sediment screening thresholds protective of aquatic benthic invertebrates were selected as the lowest of the following thresholds:

- Threshold effects levels (TELs) reported by Smith et al. (1996)
- Threshold effects concentrations (TECs) reported by MacDonald et al. (2000)

The lowest sediment screening threshold for each COI is presented in Table 2-13. Attachment 1 (Table 1) provides a summary of all sediment thresholds compiled from the above sources. Sediment COIs with no screening thresholds are presented in Table 2-14; these chemicals were not addressed further in the ERA but are noted in the uncertainty analysis.

Table 2-13. Aquatic Benthic Invertebrate Sediment Screening Thresholds

Surface Sediment COI	Screening Threshold	Unit (dw)	Source
Metals			
Arsenic	5.9	mg/kg	Smith et al. (1996)
Cadmium	0.596	mg/kg	Smith et al. (1996)
Chromium	37.3	mg/kg	Smith et al. (1996)
Copper	31.6	mg/kg	MacDonald et al. (2000)
Lead	35	mg/kg	Smith et al. (1996)
Mercury	0.174	mg/kg	Smith et al. (1996)
Nickel	18	mg/kg	Smith et al. (1996)
Zinc	121	mg/kg	MacDonald et al. (2000)
PAHs			
Anthracene	57.2	µg/kg	MacDonald et al. (2000)
Benzo(a)anthracene	31.7	µg/kg	Smith et al. (1996)
Benzo(a)pyrene	31.9	µg/kg	Smith et al. (1996)
Chrysene	57.1	µg/kg	Smith et al. (1996)
Dibenzo(a,h)anthracene	33	µg/kg	MacDonald et al. (2000)
Fluoranthene	111	µg/kg	Smith et al. (1996)
Fluorene	77.4	µg/kg	MacDonald et al. (2000)
Naphthalene	176	µg/kg	MacDonald et al. (2000)
Phenanthrene	41.9	µg/kg	Smith et al. (1996)
Pyrene	53	µg/kg	Smith et al. (1996)
Total PAHs[a]	1,610	µg/kg	MacDonald et al. (2000)
PCBs			
Total PCBs[b]	34.1	µg/kg	Smith et al. (1996)
Pesticides			
2,4′-DDD	3.54	µg/kg	Smith et al. (1996)
4,4′-DDD	3.54	µg/kg	Smith et al. (1996)
4,4′-DDE	1.42	µg/kg	Smith et al. (1996)
Total DDTs	5.28	µg/kg	MacDonald et al. (2000)

[a] Individual PAH COIs listed in Table 2-11 (acenaphthylene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, total benzofluoranthenes [benzo(b)fluoranthene and benzo(k)fluoranthene], benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3,-c,d)pyrene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) were evaluated as part of the total PAH sum.

[b] Individual PCB Aroclor COIs listed in Table 2-11 (Aroclor 1254 and Aroclor 1260) were evaluated as part of the total PCB sum.

COI – contaminant of interest
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

Table 2-14. COIs with No Aquatic Benthic Invertebrate Screening Threshold

Surface Sediment COI	
Metals	
Barium	Vanadium
Cobalt	
PAHs	
2-Methylnaphthalene	Dibenzofuran
VOCs	
Acetone	Methyl ethyl ketone
Carbon disulfide	Toluene
TPH	
TPH-gasoline range	TPH-motor oil range
TPH-diesel range	Total petroleum hydrocarbons

COI – contaminant of interest
PAH – polycyclic aromatic hydrocarbon
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 2-15 presents the results of the surface sediment screen for aquatic benthic invertebrates. Eighteen COPCs (i.e., arsenic, cadmium, copper, lead, mercury, nickel, zinc, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, pyrene, total PCBs, 2,4′-DDD, 4,4′-DDD, 4,4′-DDE, and total DDTs) were identified because maximum surface sediment concentrations were greater than the lowest sediment screening thresholds. These COPCs are evaluated further in the refined screening step (Section 2.7). Aquatic benthic invertebrate COPCs not eliminated as part of the refined COPC screen (Section 2.7) are further assessed in the aquatic benthic invertebrate risk assessment (Section 5.1.1).

Table 2-15. Aquatic Benthic Invertebrate COPC Screen Results for Surface Sediment

Surface Sediment COI	Unit (dw)	Maximum Concentration	Screening Threshold	COPC?
Metals				
Arsenic	mg/kg	7	5.9	**yes**
Cadmium	mg/kg	2	0.596	**yes**
Chromium	mg/kg	34	37.3	no
Copper	mg/kg	72	31.6	**yes**
Lead	mg/kg	56	35	**yes**
Mercury	mg/kg	0.2 J	0.174	**yes**
Nickel	mg/kg	31	18	**yes**
Zinc	mg/kg	229	121	**yes**
PAHs				
Anthracene	µg/kg	26	57.2	no
Benzo(a)anthracene	µg/kg	74	31.7	**yes**
Benzo(a)pyrene	µg/kg	83	31.9	**yes**
Chrysene	µg/kg	110	57.1	**yes**
Dibenzo(a,h)anthracene	µg/kg	6.5	33	no
Fluoranthene	µg/kg	190	111	**yes**
Fluorene	µg/kg	26	77.4	no
Naphthalene	µg/kg	61	176	no
Phenanthrene	µg/kg	120	41.9	**yes**
Pyrene	µg/kg	180	53	**yes**
Total PAHs	µg/kg	1,060	1,610	no
PCBs				
Total PCBs	µg/kg	131	34.1	**yes**
Pesticides				
2,4′-DDD	µg/kg	61 JN	3.54	**yes**
4,4′-DDD	µg/kg	47	3.54	**yes**
4,4′-DDE	µg/kg	150	1.42	**yes**
Total DDTs	µg/kg	250	5.28	**yes**

COI – contaminant of interest
COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
N – tentative identification
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
Bold identifies COPCs.

2.6.1.3 Surface Water COPC Screen for Aquatic Benthic Invertebrates

COPCs for aquatic benthic invertebrates were also determined using surface water data. Surface water COPCs were identified by comparing maximum surface water concentrations to chronic water screening thresholds. Surface water COIs with maximum detected concentrations greater than the water screening thresholds were considered COPCs for aquatic benthic invertebrates.

Chronic water screening thresholds protective of aquatic species (including aquatic invertebrates) were selected based on the lower of national water quality criteria protective of freshwater organisms (EPA ambient water quality criteria [AWQC]) or proposed Oregon water quality criteria (Oregon Administrative Rule [OAR] 340-41, Table 33). For those COIs for which neither AWQC nor Oregon water quality criteria were available, the Tier 2 values provided by Suter and Tsao (1996) were used. Water screening thresholds for surface water COIs are presented in Table 2-16. Attachment 1 (Table 2) also provides a summary of the water thresholds.

Table 2-16. Selected Chronic Water Screening Thresholds

Surface Water COI	Unit	Screening Threshold	Source
Metals			
Arsenic	µg/L	150[a]	EPA AWQC (2009a)
Barium	µg/L	4[b]	Tier II (Suter and Tsao 1996)
Copper	µg/L	1.3[a, c]	EPA AWQC (2009a)
VOCs			
Acetone	µg/L	1,500	Tier II (Suter and Tsao 1996)

a Threshold expressed as the dissolved metal concentration.

b Threshold expressed as the total metal concentration.

c Threshold was hardness adjusted based on the average Force Lake hardness (10.7 mg/L $CaCO_3$).

AWQC – ambient water quality criteria

COI – contaminant of interest

EPA – US Environmental Protection Agency

VOC – volatile organic compound

Table 2-17 presents the results of the surface water screen. Two COPCs (i.e., barium and copper) were identified and are evaluated further in the refined screening step (Section 2.7).

Table 2-17. COPC Screen Results for Surface Water

Surface Water COI	Unit	Maximum Concentration	Screening Threshold	COPC?
Metals				
Arsenic (dissolved)	µg/L	1	150	no
Barium (total)	µg/L	31	4	**yes**
Copper (dissolved)	µg/L	4.0	1.3	**yes**
VOCs				
Acetone	µg/L	6.5	1,500	no

COI – contaminant of interest
COPC – contaminant of potential concern
VOC – volatile organic compound
Bold identifies COPCs.

2.6.2 Terrestrial Invertebrates

This section presents the COPC screen for terrestrial invertebrates, which is summarized in Figure 2-5.

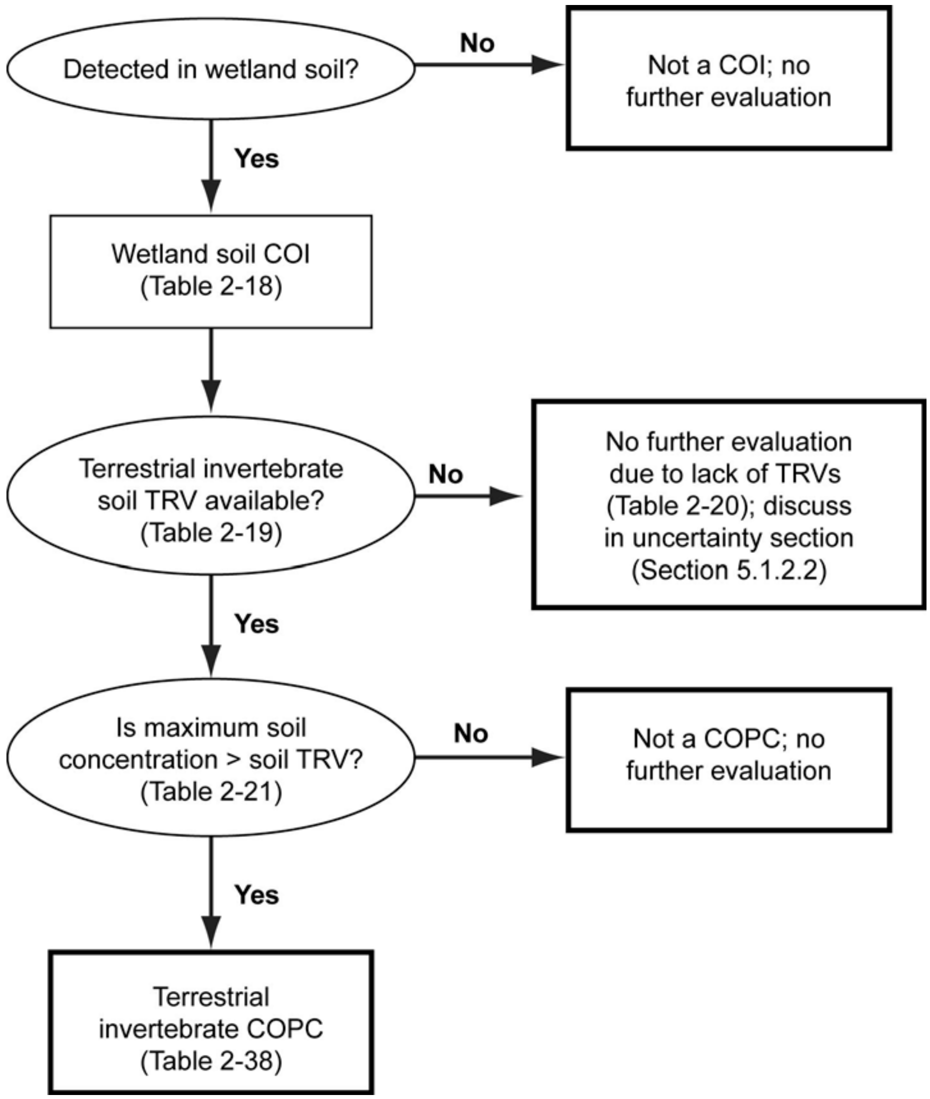


Figure 2-5. COPC Screening Process for Terrestrial Invertebrates

2.6.2.1 COIs for Terrestrial Invertebrates

The first step of the COPC screening process for terrestrial invertebrates was to generate a list of COIs. Wetland soil COIs for terrestrial invertebrates were defined as any analyte detected in at least one wetland soil sample. Table 2-18 presents the wetland soil COIs for terrestrial benthic invertebrates.

Table 2-18. Chemicals Detected in Wetland Soil and Thus Identified as COIs

Wetland Soil COI[a]	
Metals	
Aluminum	Lead
Antimony	Manganese
Arsenic	Mercury
Barium	Nickel
Beryllium	Selenium
Cadmium	Silver
Chromium	Vanadium
Cobalt	Zinc
Copper	
PAHs	
2-Methylnaphthalene	Dibenzo(a,h)anthracene
Acenaphthene	Dibenzofuran
Acenaphthylene	Fluoranthene
Anthracene	Fluorene
Benzo(a)anthracene	Indeno(1,2,3-cd)pyrene
Benzo(a)pyrene	Naphthalene
Benzo(b)fluoranthene	Phenanthrene
Benzo(g,h,i)perylene	Pyrene
Benzo(k)fluoranthene	Total HPAHs
Total benzofluoranthenes	Total LPAHs
Chrysene	Total PAHs
Phthalates	
Bis(2-ethylhexyl) phthalate	Di-n-butyl phthalate
Butyl benzyl phthalate	
Other SVOCs	
1,4-Dichlorobenzene	Biphenyl
4-Methylphenol	Carbazole
Acetophenone	Hexachlorobenzene
Benzaldehyde	Pentachlorophenol
Benzoic acid	Phenol
Benzyl alcohol	
PCBs	
Aroclor 1248	Aroclor 1260
Aroclor 1254	Total PCBs
Pesticides	
2,4′-DDD	4,4′-DDT
2,4′-DDE	Total DDTs
2,4′-DDT	delta-BHC
4,4′-DDD	Methoxychlor

Table 2-18. Chemicals Detected in Wetland Soil and Thus Identified as COIs

Wetland Soil COI[a]	
4,4′-DDE	
VOCs	
1,2,4-Trimethylbenzene	Methyl ethyl ketone
Acetone	Methyl isobutyl ketone
Benzene	Tetrachloroethene
Carbon disulfide	Toluene
cis-1,2-Dichloroethene	Trichloroethene
p-Cymene	o-Xylene
Dichloromethane	m,p-Xylene
Ethylbenzene	Total xylene
TPH	
TPH-gasoline range	TPH-motor oil range (HCID)
TPH-diesel range (HCID)	TPH-motor oil range
TPH-diesel range	Total petroleum hydrocarbons

[a] Calcium, iron, magnesium, potassium, and sodium were detected historically; however, these analytes were not evaluated as COIs because they were not analyzed as part of Phase 1 or Phase 2 sampling events for the RI and are not expected to be toxic to ecological ROCs.

BHC –hexachlorocyclohexane
COI – contaminant of interest
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HCID – hydrocarbon identification
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RI – remedial investigation
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

2.6.2.2 COPC Screen for Terrestrial Invertebrates

In the second step, COPCs for terrestrial invertebrates were identified in wetland soil by comparing maximum detected COI concentrations in soil to terrestrial invertebrate-specific screening thresholds. COIs with maximum detected concentrations greater than soil screening thresholds were considered COPCs for terrestrial invertebrates. Terrestrial invertebrate-specific soil screening thresholds were selected as the lowest terrestrial invertebrate-specific threshold from the following sources:

- EPA Ecological Soil Screening Levels (SSLs) (2007b) protective of soil invertebrates
- Oak Ridge National Laboratory (ORNL) soil data for invertebrates (Efroymson et al. 1997)
- DEQ soil screening level values protective of terrestrial invertebrates (2001)

The lowest soil screening threshold for each COI is presented in Table 2-19. Attachment 1 (Table 3) provides a summary of all soil screening values compiled from the above sources. Soil COIs with no screening values are presented in Table 2-20; these chemicals were not addressed further in the ERA but are noted in the uncertainty analysis.

Table 2-19. Terrestrial Invertebrate Soil Screening Thresholds

Wetland Soil COI	Screening Threshold	Unit (dw)	Source
Metals			
Aluminum	600	mg/kg	DEQ (2001)
Antimony	78	mg/kg	Ecological SSL (EPA 2005a)
Arsenic	60	mg/kg	DEQ (2001); Efroymson et al. (1997)
Barium	330	mg/kg	Ecological SSL (EPA 2005b)
Beryllium	40	mg/kg	Ecological SSL (EPA 2005c)
Cadmium	20	mg/kg	DEQ (2001); Efroymson et al. (1997)
Chromium	0.4	mg/kg	DEQ (2001); Efroymson et al. (1997)
Cobalt	1,000	mg/kg	DEQ (2001)
Copper	50	mg/kg	DEQ (2001); Efroymson et al. (1997)
Lead	500	mg/kg	DEQ (2001); Efroymson et al. (1997)
Manganese	100	mg/kg	DEQ (2001)
Mercury	0.1	mg/kg	DEQ (2001); Efroymson et al. (1997)
Nickel	200	mg/kg	DEQ (2001); Efroymson et al. (1997)
Selenium	4.1	mg/kg	Ecological SSL (EPA 2007d)
Silver	50	mg/kg	DEQ (2001)
Zinc	120	mg/kg	Ecological SSL (EPA 2007e)
PAHs			
Total LPAHs[a]	29,000	µg/kg	Ecological SSL (EPA 2007c)
Total HPAHs[b]	18,000	µg/kg	Ecological SSL (EPA 2007c)
Other SVOCs			
1,4-Dichlorobenzene	20,000	µg/kg	DEQ (2001); Efroymson et al. (1997)
Hexachlorobenzene	1,000,000	µg/kg	DEQ (2001)
Pentachlorophenol	4,000	µg/kg	DEQ (2001)
Phenol	30,000	µg/kg	DEQ (2001); Efroymson et al. (1997)

[a] Individual PAH COIs listed in Table 2-18 (acenaphthylene, acenaphthene, anthracene, fluorene, naphthalene, and phenanthrene) were evaluated as part of the total LPAH sum.

[b] Individual PAH COIs listed in Table 2-18 (benzo(a)anthracene, benzo(a)pyrene, total benzofluoranthenes [benzo(b)fluoranthene and benzo(k)fluoranthene], benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3,-c,d)pyrene, fluorene, and pyrene) were evaluated as part of the total HPAH sum.

COI – contaminant of interest
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EPA – US Environmental Protection Agency
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
SSL – soil screening level
SVOC – semivolatile organic compound

Table 2-20. COIs with No Terrestrial Invertebrate Screening Threshold

Wetland Soil COI	
Metals	
Vanadium	
Phthalates	
Bis(2-ethylhexyl) phthalate	Di-n-butyl phthalate
Butyl benzyl phthalate	
PAHs	
2-Methylnaphthlene	Dibenzofuran
Other SVOCs	
4-Methylphenol	Benzyl alcohol
Acetophenone	Biphenyl
Benzaldehyde	Carbazole
Benzoic acid	
PCBs	
Aroclor 1248	Aroclor 1260
Aroclor 1254	Total PCBs
Pesticides	
2,4′-DDD	4,4′-DDT
2,4′-DDE	Total DDTs
2,4′-DDT	delta-BHC
4,4′-DDD	Methoxychlor
4,4′-DDE	
VOCs	
1,2,4-Trimethylbenzene	Methyl ethyl ketone
Acetone	Methyl isobutyl ketone
Benzene	Tetrachloroethene
Carbon disulfide	Toluene
cis-1,2-Dichloroethene	Trichloroethene
p-Cymene	o-Xylene
Dichloromethane	m,p-Xylene
Ethylbenzene	Total xylene
TPH	
TPH-gasoline range	TPH-motor oil range (HCID)
TPH-diesel range (HCID)	TPH-motor oil range
TPH-diesel range	Total petroleum hydrocarbons

BHC – hexachlorocyclohexane
COI – contaminant of interest
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HCID – hydrocarbon identification
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Table 2-21 presents the results of the wetland soil screen for terrestrial invertebrates. Eight COPCs (i.e., aluminum, barium, chromium, copper, manganese, mercury, zinc, and total HPAHs) were identified based on soil data from surface (upper 6 inches) and intermediate (6 to 12 inches[16]) depths because maximum soil concentrations were greater than the lowest soil screening thresholds. These COPCs are evaluated further in the refined screening step (Section 2.7). Terrestrial invertebrate COPCs not eliminated as part of the refined COPC screen (Section 2.7) are further assessed in the terrestrial invertebrate risk assessment (Section 5.1.2).

Table 2-21. Terrestrial Invertebrate COPC Screen Results for Soil

Wetland Soil COI	Unit (dw)	Maximum Concentration	Screening Threshold	COPC?
Metals				
Aluminum	mg/kg	12,100	600	**yes**
Antimony	mg/kg	8.4 J	78	no
Arsenic	mg/kg	53.1	60	no
Barium	mg/kg	481	330	**yes**
Beryllium	mg/kg	0.544	40	no
Cadmium	mg/kg	4	20	no
Chromium	mg/kg	149	0.4	**yes**
Cobalt	mg/kg	34.3	1,000	no
Copper	mg/kg	1,240 J	50	**yes**
Lead	mg/kg	320	500	no
Manganese	mg/kg	1,090	100	**yes**
Mercury	mg/kg	0.4	0.1	**yes**
Nickel	mg/kg	48	200	no
Selenium	mg/kg	1.1	4.1	no
Silver	mg/kg	1.5	50	no
Zinc	mg/kg	748	120	**yes**
PAHs				
Fluorene	µg/kg	417 J	30,000	no
Total HPAHs	µg/kg	57,000	18,000	**yes**
Total LPAHs	µg/kg	12,200	29,000	no
Other SVOCs				
1,4-Dichlorobenzene	µg/kg	19 J	20,000	no
Hexachlorobenzene	µg/kg	42	1,000,000	no
Pentachlorophenol	µg/kg	80 J	4,000	no
Phenol	µg/kg	498 J	30,000	no

COI – contaminant of interest
COPC – contaminant of potential concern
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
J – estimated concentration
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
SVOC – semivolatile organic compound

Bold identifies COPCs.

[16] Berm soil samples included soil collected from the depth interval of 6 to 24 inches.

2.6.3 Fish

This section presents the COPC screen for the fish ROCs (pumpkinseed and brown bullhead), which is summarized in Figure 2-6.

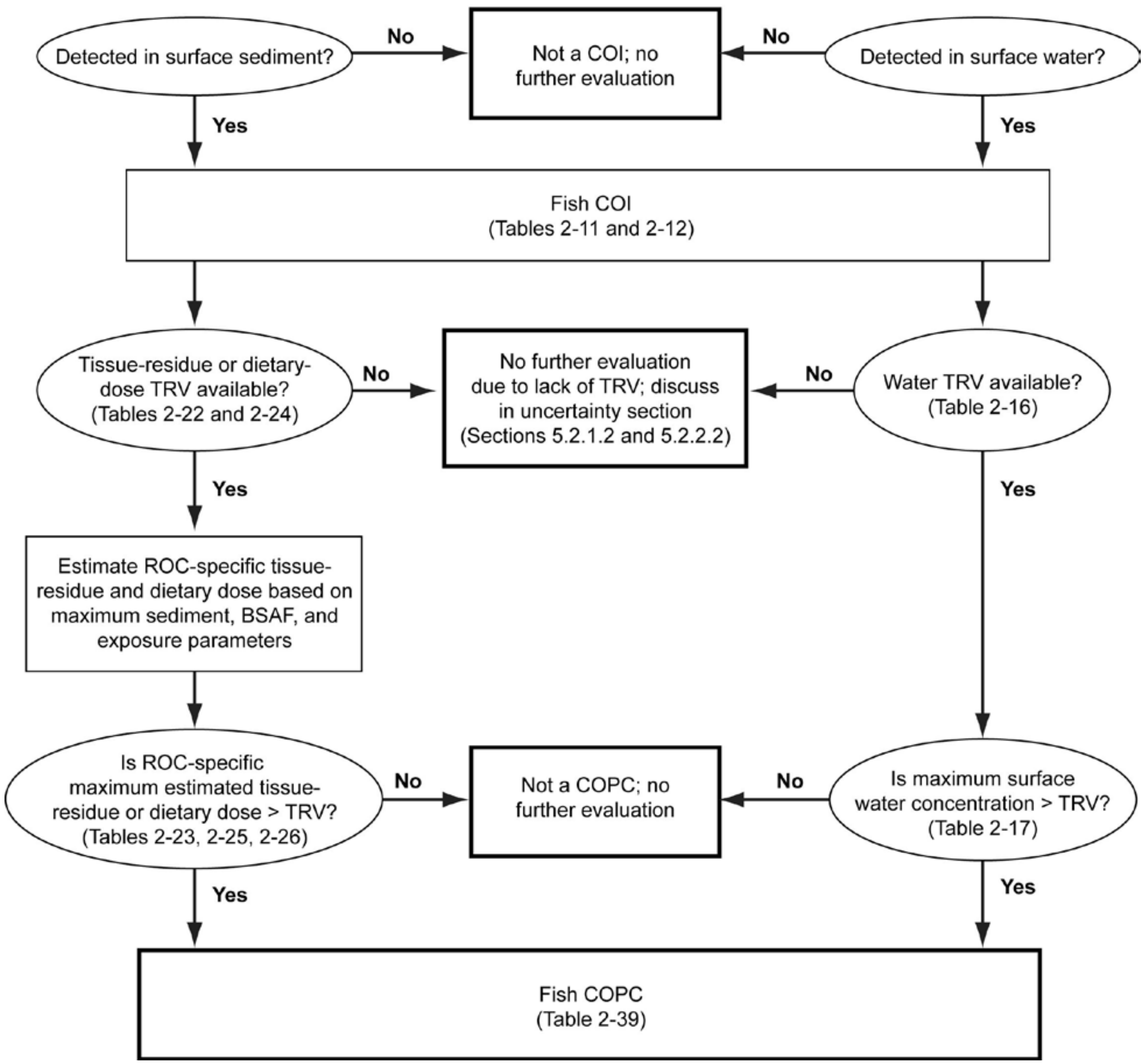


Figure 2-6. COPC Screening Process for Fish ROCs

2.6.3.1 COIs for Fish

The first step in the COPC screen for fish was the identification of COIs. COIs were defined as any analyte detected in surface sediment or surface water. The COIs are presented in Tables 2-11 and 2-12.

COPCs were then developed from the COI lists. For fish, three screens were conducted: 1) a fish tissue-residue screen of all surface sediment COIs, excepted surface sediment COIs evaluated using a dietary approach, 2) a surface water screen of all surface water COIs, and 3) a dietary screen of all surface sediment COIs that are metabolized or regulated by fish (all metals except mercury and all PAHs).These screens are discussed below.

2.6.3.2 Tissue-Residue COPC Screen for Fish

Tissue-residue COPCs for fish ROCs were identified by comparing maximum estimated COI concentrations in fish tissue to tissue-residue no-observed-adverse-effects level (NOAEL)[17] toxicity reference values (TRVs). COIs with maximum concentrations greater than the NOAEL TRVs were identified as COPCs for fish for further evaluation in the ERA in Section 5.2.

A comprehensive literature search was conducted to identify appropriate toxicity studies for the development of fish tissue-residue NOAEL TRVs. The following sources were searched to identify acceptable toxicity studies in the literature for tissue-residue COIs identified for fish:

- BIOSIS
- Environmental Residue Effects Database
- EPA's ECOTOX database
- Jarvinen and Ankley (1999)

Original sources of toxicity data were obtained and reviewed to verify effects data summarized in the databases as well as the suitability of the studies. The databases were searched for studies that evaluated effects on survival, growth, and reproduction.

Acceptable toxicological data that met the following criteria were compiled for fish:

- The chemical concentration in whole body tissue was analyzed as part of the study.
- All selected TRVs were based on laboratory toxicological studies (not field studies). Laboratory studies were used because of the uncertainty surrounding results obtained from field studies (e.g., presence of other chemicals or other confounding factors).
- Studies had to have experimental controls, replicates, and a statistical analysis of the results.

[17] NOAEL TRVs are concentrations below which no adverse effects have been observed.

- Selected TRVs based on exposure via diet, sediment, or water were preferred.
- Other exposure routes including intraperitoneal (IP) or egg injection or oral gavage were only used when no other studies were found.

After the literature search was conducted, all acceptable studies for TRV derivation were compiled. Attachment 1 (Table 4) provides a summary of all fish tissue-residue NOAEL and lowest-observed-adverse-effects level (LOAEL)[18] TRVs reviewed from the literature. The NOAEL TRV was selected as the highest no-effect value below the lowest LOAEL TRV based on the same endpoint. If no NOAEL TRV of the same endpoint was available below the selected LOAEL, an uncertainty factor (UF) was used based on guidance from EPA Region 10 (1997b).

Selected tissue-residue NOAEL TRVs are presented in Table 2-22. No tissue TRVs were available for the following tissue COIs: acetone, carbon disulfide, methyl ethyl ketone, toluene, or 4 TPH mixtures; these chemicals are noted in the uncertainty analysis.

Table 2-22. Selected Tissue-Residue NOAEL TRVs for the Fish COPC Screen

Tissue-Residue COI	NOAEL TRV (µg/kg ww)	Endpoint	Source
Metals			
Mercury	230	survival	Webber and Haines (2003)
PCBs			
Total PCBs[a]	104	reproduction	Hugla and Thome (1999)
Pesticides			
Total DDTs[b]	1,800	survival	Allison et al. (1964)

[a] Individual PCB Aroclor COIs listed in Table 2-11 (Aroclor 1254 and Aroclor 1260) were evaluated as part of the total PCB sum.

[b] Individual DDT metabolite COIs listed in Table 2-11 (2,4′-DDD, 4,4′-DDD, and 4,4′-DDE) were evaluated as part of the total DDT sum.

COI – contaminant of interest
DDT – dichlorodiphenyltrichloroethane
NOAEL – no-observed-adverse-effect level
PCB – polychlorinated biphenyl
TRV – toxicity reference value
ww – wet weight

For comparison with the NOAEL TRVs, COI concentrations in fish tissue were estimated using fish biota-sediment accumulation factors (BSAFs) and assumptions presented in Attachment 2 (Tables 1, 2, and 5). Total PCB and total DDT BSAFs were based on tissue and sediment data that were lipid and organic-carbon (OC)-normalized, respectively. The average lipid concentrations reported by EPA (2008) for pumpkinseed and brown bullhead (3.1% and 2.6%, respectively) were used to estimate

[18] LOAEL TRVs are the lowest concentrations at which an adverse effect occurred. Acute or subchronic LOAELs were divided by a UF of 10; chronic or critical life-stage LOAELs were divided by a UF of 5; and LC50 (i.e., concentration that is lethal to 50% of an exposed population) (or similar) LOAELs were divided by a UF of 50.

total PCB and total DDT tissue concentrations. An average fish moisture content (72%) reported by EPA (1993b) was used to estimate wet weight mercury concentrations in fish tissue from the dry-weight-based mercury BSAF.

Table 2-23 presents the results of the fish tissue COPC screen. Total PCBs was identified as a COPC for both pumpkinseed and brown bullhead. Total PCBs are evaluated further in the refined COPC assessment (Section 2.7).

Table 2-23. Results of the COPC Screen for Fish Using the Tissue-Residue Approach

Tissue-Residue COI	BSAF		Maximum Sediment Concentration	Estimated Maximum Tissue Concentration			COPC?
	Value	Unit		Unit (ww)	C_{fish}[a]	NOAEL TRV	
Pumpkinseed							
Mercury	0.38	dw/dw	0.2 J mg/kg dw	mg/kg	0.021	0.23	no
Total PCBs	6.45	lipid/OC	1.83 mg/kg OC	µg/kg	370	104	**yes**
Total DDTs	3.0	lipid/OC	3.7 mg/kg OC	µg/kg	340	1,800	no
Brown Bullhead							
Mercury	0.38	dw/dw	0.2 J mg/kg dw	mg/kg	0.021	0.23	no
Total PCBs	6.45	lipid/OC	1.83 mg/kg OC	µg/kg	310	104	**yes**
Total DDTs	3.0	lipid/OC	3.7 mg/kg OC	µg/kg	290	1,800	no

[a] C_{fish} was estimated using BSAFs and ROC-specific exposure assumptions. When the sediment concentration was dw, the following equation was used: C_{fish} (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment concentration was OC-normalized, the following equation was used: C_{fish} (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. For pumpkinseed, average percent moisture and percent lipids were 72 and 3.1%, respectively. For brown bullhead, average percent moisture and percent lipids were 72 and 2.6%, respectively. See Attachment 2 for details on how BSAFs and assumptions were selected.

BSAF – biota-sediment accumulation factor
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
NOAEL – no-observed-adverse-effect level
OC – organic carbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
ww – wet weight

Bold text identifies COPCs.

2.6.3.3 Surface Water COPC Screen for Fish

The second COPC screen conducted for fish involved the use of surface water data. Surface water COPCs for fish were identified through a comparison of maximum surface water concentrations to chronic water screening thresholds. Surface water COPCs for fish were identified using the same water screening thresholds (Table 2-16) as used to identify surface water COPCs for aquatic benthic invertebrates. Consequently, the same COPCs identified in surface water for aquatic benthic invertebrates were identified as COPCs in surface water for fish

(Table 2-17).These two COPCs (barium and copper) are evaluated further in the refined screening step (Section 2.7).

2.6.3.4 Dietary Dose COPC Screen for Fish

The third COPC screen conducted for fish was conducted using a dietary dose approach for chemicals that are metabolized or regulated by fish (i.e., metals [except mercury] and PAHs). To identify dietary COPCs for fish ROCs, maximum detected COI concentrations in sediment and maximum estimated concentrations in potential prey items for a given ROC (i.e., pumpkinseed and brown bullhead) were used to estimate a maximum dietary dose (see method described in Section 3.2.2). COI concentrations in fish prey were estimated using BSAFs and assumptions presented in Attachment 2 (Tables 1 through 5). Maximum dietary doses were then compared to dietary-dose NOAEL TRVs; COIs with maximum doses that were greater than the NOAEL TRVs were identified as COPCs.

A comprehensive literature search was conducted on published toxicity studies to date to identify appropriate toxicity studies for the development of dietary-dose TRVs. The following sources were searched to identify acceptable toxicity studies in the literature in order to establish dietary-dose TRVs for fish dietary COIs:

- BIOSIS
- Environmental Residue Effects Database
- EPA's ECOTOX database

Original sources of toxicity data were obtained and reviewed to verify effects data summarized in the databases as well as the suitability of the studies. The databases were searched for studies that evaluated effects on survival, growth, and reproduction.

Acceptable toxicological data that met the following criteria were compiled:

- All studies were based on dietary exposure.
- All selected TRVs were based on laboratory toxicological studies (not field studies). Laboratory studies were used because of the uncertainty surrounding results obtained from field studies (e.g., presence of other chemicals or other confounding factors).
- Studies were excluded if they did not have experimental controls, replicates, and a statistical analysis of the results.

Dietary-dose TRVs (in mg/kg bw/day) were calculated based on the information provided in the acceptable studies. Most toxicological studies presented reported concentrations in mg/kg food; thus, it was necessary to calculate a daily dose (mg/kg bw/day) based on ROC body weight, ingestion rate (IR), and the percent moisture of the food. If this information was not provided in the study, default values were used from the following sources:

- **Body weight:** If no body weight data were provided in the study or data provided were not considered representative, body weights for fish were estimated from other literature sources or toxicity studies.
- **Ingestion rate:** If no ingestion rates were provided in the study, they were estimated from other literature sources for the same species. If no other literature sources were available, an ingestion rate of 2% food (dw)/kg bw/day was assumed as a conservative estimate based on the food ingestion rates commonly reported for laboratory toxicity studies.
- **Percent moisture:** A commercial feed or pelleted diet was assumed to approximate a dw concentration, and 80% moisture was assumed when the diet consisted of organism prey (e.g., invertebrate prey).

Once TRVs were calculated for all studies, NOAEL TRVs were established for COIs using the same criteria described in Section 2.6.3.2. Selected fish dietary TRVs are presented in Table 2-24. Attachment 1 (Tables 5 through 7) provides a summary of all dietary-dose NOAEL and LOAEL TRVs reviewed from the literature. No dietary-dose TRVs were available for five fish COIs: barium, cobalt, nickel, 2-methylnaphthalene, and dibenzofuran; these chemicals are noted in the uncertainty analysis. Individual PAH COIs (other than benzo[a]pyrene) were evaluated using TRVs for total PAHs and benzo(a)pyrene.

Table 2-24. Selected Dietary-Dose NOAEL TRVs for the Fish COPC Screen

Dietary COI	Test Species	NOAEL (mg/kg bw/day)	Endpoint	Source
Metals				
Arsenic	rainbow trout	0.40	growth	Oladimeji et al. (1984)
Cadmium	rockfish	0.0020[a]	growth	Kim et al. (2004); Kang et al. (2005)
Chromium	grey mullet	9.42	growth	Walsh et al. (1994)
Copper	rockfish	1.0	growth	Kang et al. (2005)
Lead	rainbow trout	134	growth	Goettl et al. (1976)
Silver	rainbow trout	70	growth	Galvez and Wood (1999)
Vanadium	rainbow trout	0.039[a]	growth	Hilton and Bettger (1988)
Zinc	rainbow trout	19	growth	Takeda and Shimma (1977)
PAHs				
Benzo(a)pyrene	English sole	0.66	growth	Rice et al. (2000)
Total PAHs[b]	Chinook salmon	6.1[c]	growth	Meador et al. (2006)

[a] NOAEL was estimated using a UF of 5 (chronic LOAEL to NOAEL).

[b] Individual PAH COIs listed in Table 2-11 (acenaphthylene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, total benzofluoranthenes [benzo(b)fluoranthene and benzo(k)fluoranthene], benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3,-c,d)pyrene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) were evaluated as part of the total PAH sum.

[c] Mixture contained the following 21 PAHs included in the Meador et al. (2006) diet: naphthalene, 2-methylnaphthalene, dimethylnaphthalene, dibenzothiophene, acenaphthene, fluorene, 1,8-dimethyl(9H)fluorene, phenanthrene, 9-ethylphenanthrene, 9-ethyl-10-methylphenanthrene, 1-methyl-7-isopropylphenanthrene, anthracene, fluoranthene, pyrene, methyl pyrene, benzo(a)anthracene, chrysene, benz(a)pyrene, benzo(k)fluoranthene, benzo(g,h,i)perylene, and dibenzanthracene.

bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
dw – dry weight
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
UF – uncertainty factor

Tables 2-25 and 2-26 present the results of the dietary COPC screen for fish ROCs. Three COPCs (i.e., cadmium, copper, and vanadium) were identified for both pumpkinseed and brown bullhead. These COPCs are evaluated further in the refined screening step (Section 2.7). Fish dietary COPCs not eliminated as part of the refined COPC screen (Section 2.7) are further assessed in the fish risk assessment (Section 5.2).

Table 2-25. Results of the Pumpkinseed Dietary COPC Screen

Dietary COI	Sediment Concentration		Aquatic Invertebrate BSAF		Prey Tissue Concentration		Estimated Maximum Dose			COPC?
	C_{sed} [a]	Unit	BSAF Value	Unit	$C_{aquat\ invert}$ [b]	Unit	$Dose_{diet}$ [c]	NOAEL TRV	Unit	
Metals										
Arsenic	7	mg/kg dw	0.24	tiss dw/sed dw	0.35	mg/kg ww	0.04	0.4	mg/kg bw/day	no
Cadmium	2	mg/kg dw	3.438	tiss dw/sed dw	1.4	mg/kg ww	0.15	0.002	mg/kg bw/day	**yes**
Chromium	34	mg/kg dw	0.206	tiss dw/sed dw	1.5	mg/kg ww	0.17	9.42	mg/kg bw/day	no
Copper	72	mg/kg dw	2.14	tiss dw/sed dw	32	mg/kg ww	**3.5**	1	mg/kg bw/day	**yes**
Lead	56	mg/kg dw	0.331	tiss dw/sed dw	3.9	mg/kg ww	0.43	134	mg/kg bw/day	no
Vanadium	74	mg/kg dw	1	tiss dw/sed dw	16	mg/kg ww	**1.7**	0.039	mg/kg bw/day	**yes**
Zinc	229	mg/kg dw	3.473	tiss dw/sed dw	170	mg/kg ww	**18**	19	mg/kg bw/day	no
PAHs										
Benzo(a)pyrene	1.3	mg/kg OC	0.383	tiss lipid/sed OC	6.0	µg/kg ww	0.65	660	µg/kg bw/day	no
Total PAHs	19.8	mg/kg OC	0.923	tiss lipid/sed OC	220	µg/kg ww	24	6100	µg/kg bw/day	no

a C_{sed} is represented by maximum sediment concentration.

b $C_{aquatic\ invert}$ was estimated from C_{sed} (either as a dw concentration or an OC-normalized concentration) and aquatic benthic invertebrate BSAF. When the sediment concentration was dw, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment concentration was OC-normalized, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. $C_{aquatic\ invert}$ was converted to ww assuming a moisture content of 79% or a lipid content of 1.2%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

c $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-5, and assumption that diet is comprised of 100% aquatic invertebrates.

BSAF – biota-sediment accumulation factor
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
dw – dry weight
NOAEL – no-observed-adverse-effect level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
TRV – toxicity reference value
ww – wet weight

Bold identifies COPCs.

Table 2-26. Results of the Brown Bullhead Dietary COPC Screen

Dietary COI	Sediment Concentration		BSAF			Prey Tissue Concentration			Estimated Maximum Dose			COPC?
	C_{sed}[a]	Unit	Fish BSAF	Aquatic Invert BSAF	Unit	C_{fish}[b]	$C_{aquat\ invert}$[c]	Unit	$Dose_{diet}$[d]	NOAEL TRV	Unit	
Metals												
Arsenic	7	mg/kg dw	0.12	0.24	tiss dw/sed dw	0.24	0.35	mg/kg ww	0.032	0.4	mg/kg bw/day	no
Cadmium	2	mg/kg dw	0.785	3.438	tiss dw/sed dw	0.44	1.4	mg/kg ww	**0.089**	0.002	mg/kg bw/day	**yes**
Chromium	34	mg/kg dw	0.043	0.206	tiss dw/sed dw	0.41	1.5	mg/kg ww	0.14	9.42	mg/kg bw/day	no
Copper	72	mg/kg dw	1	2.14	tiss dw/sed dw	20	32	mg/kg ww	**2.1**	1	mg/kg bw/day	**yes**
Lead	56	mg/kg dw	0.18	0.331	tiss dw/sed dw	2.8	3.9	mg/kg ww	0.33	134	mg/kg bw/day	no
Vanadium	74	mg/kg dw	1	1	tiss dw/sed dw	21	16	mg/kg ww	**1.2**	0.039	mg/kg bw/day	**yes**
Zinc	229	mg/kg dw	1.83	3.473	tiss dw/sed dw	120	170	mg/kg ww	11	19	mg/kg bw/day	no
PAHs												
Benzo(a)pyrene	1.3	mg/kg OC	0.0021	0.383	tiss lipid/sed OC	0.1	6	µg/kg ww	0.36	660	µg/kg bw/day	no
Total PAHs	19.8	mg/kg OC	0.0299	0.923	tiss lipid/sed OC	22	220	µg/kg ww	13	6,100	µg/kg bw/day	no

[a] C_{sed} is represented by maximum sediment concentration.

[b] C_{fish} was estimated from C_{sed} (as a dw concentration or an OC-normalized concentration) and a fish BSAF. When the sediment concentration was dw, the following equation was used: C_{fish} (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment concentration was OC-normalized, the following equation was used: C_{fish} (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. C_{fish} was converted to ww assuming a moisture content of 72% or a lipid content of 3.7%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[c] $C_{aquatic\ invert}$ was estimated from C_{sed} (either as a dw concentration or an OC-normalized concentration) and aquatic benthic invertebrate BSAF. When the sediment concentration was dw, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment concentration was OC-normalized, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. $C_{aquatic\ invert}$ was converted to ww assuming a moisture content of 79% or a lipid content of 1.2%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[d] $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-5, and assumption that diet is composed of 10% fish and 90% aquatic invertebrates.

BSAF – biota-sediment accumulation factor
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
dw – dry weight
NOAEL – no-observed-adverse-effect level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
TRV – toxicity reference value
ww – wet weight

Bold identifies COPCs

2.6.4 Aquatic Birds

This section presents the COPC screen for the two aquatic bird ROCs (ruddy duck and great blue heron), which is summarized in Figure 2-7.

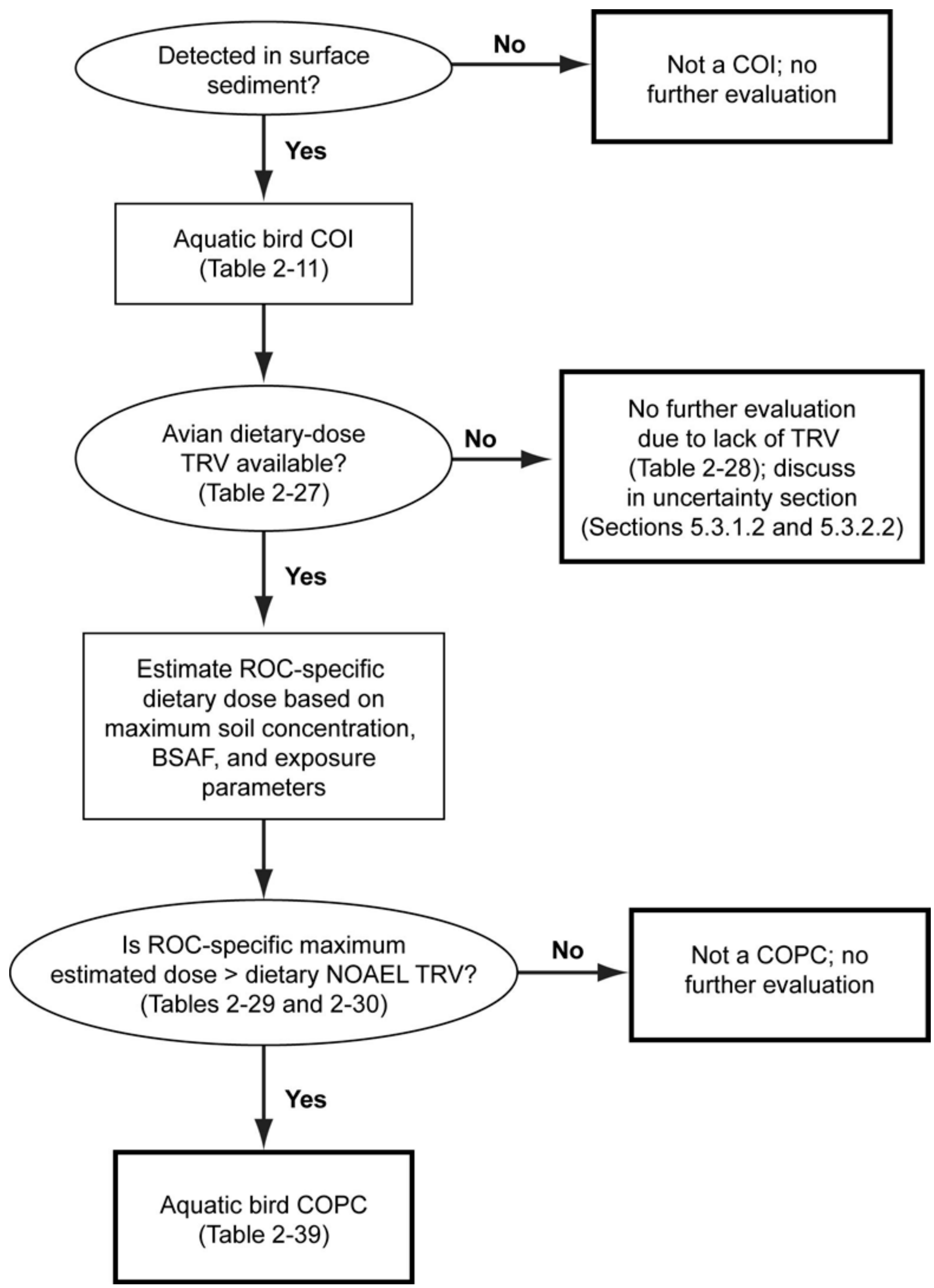


Figure 2-7. COPC Screening Process for Aquatic Bird ROCs

2.6.4.1 COIs for Aquatic Birds

The first step in the COPC screen for aquatic birds was the identification of COIs. COIs were defined as any analyte detected in surface sediment (see Table 2-11).

2.6.4.2 COPC Screen for Aquatic Birds

In the next step to identify COPCs for each of the aquatic bird ROCs, maximum detected concentrations of COIs in sediment and maximum estimated COI concentrations in potential prey items for each ROC were used to estimate a maximum dietary dose (see method described in Section 3.2.2). COI concentrations in prey were estimated using BSAFs and assumptions presented in Attachment 2 (Tables 1 through 5). Maximum dietary doses were then compared to dietary-dose NOAEL TRVs; COIs with maximum doses that were greater than the NOAEL TRVs were identified as COPCs.

A comprehensive literature search was conducted on published toxicity studies to date to identify appropriate toxicity studies for the development of dietary-dose TRVs. The following sources were searched to identify acceptable toxicity studies in the literature to establish dietary-dose TRVs for aquatic birds:

- BIOSIS
- EPA's ECOTOX database
- National Library of Medicine's TOXNET database
- US Geological Survey's Contaminant Hazard Review series
- ORNL's database
- EPA's Integrated Risk Information System (IRIS) database
- Agency for Toxic Substances and Disease Registry (ATSDR)

Original sources of toxicity data were obtained and reviewed to verify effects data summarized in the databases as well as the suitability of the studies. The databases were searched for studies that evaluated effects on survival, growth, and reproduction.

Acceptable toxicological data that met the following criteria were compiled:

- Studies conducted based on dietary dose were preferred. As with tissue-residue TRVs, other exposure routes, including IP or egg injection or oral gavage, were used when no other studies were found. Drinking water studies were not used because of differences in the bioavailability of chemicals in water. Non-relevant exposure pathways (e.g., inhalation or absorption) were also not used.
- All selected TRVs were based on laboratory toxicological studies (not field studies). Laboratory studies were used because of the

uncertainty surrounding results obtained from field studies (e.g., presence of other chemicals or other confounding factors).

- Studies were excluded if they did not have experimental controls, replicates, and a statistical analysis of the results.
- Egg production studies using chicken or quail, such as Edens and Garlich (1983) and Edens et al. (1976), are highly uncertain because these species have been bred based on high egg-laying rates. These studies were not used.
- Toxicity results based on tests with chemical species considered unlikely to occur at the Study Area (e.g., the fungicide methylmercury dicyandiamide for determining a mercury TRV) were not considered.

Dietary-dose TRVs (in mg/kg bw/day) were calculated based on the information provided in the studies. Most toxicological studies presented reported concentrations in mg/kg food; thus it was necessary to calculate a daily dose (mg/kg bw/day) based on ROC body weight, IR, and the percent moisture of the food. If this information was not provided in the study, default values were used from the following sources:

- **Body weight:** Body weights were selected from EPA's *Wildlife Exposure Factors Handbook* (1993b).
- **Ingestion rate:** Allometric equations were used for birds (Nagy 2001), and National Research Council (NRC) data were used for chicks (NRC 1994, 1984).
- **Percent moisture:** Food concentrations were generally reported on a wet-weight basis. However, when concentrations were reported on a dry-weight basis and no percent moisture was provided in the study, a published value from NRC was used based on the diet of the test species (NRC 1994).

Once TRVs had been calculated for all studies, NOAEL TRVs were established for COIs using the same criteria described in Section 2.6.3.2. Selected bird dietary TRVs are presented in Table 2-27. Attachment 1 (Tables 5 through 7) provides a summary of all dietary-dose NOAEL and LOAEL TRVs reviewed from the literature. The COIs for which no aquatic bird dietary-dose TRV could be developed are presented in Table 2-28; these chemicals will be noted in the uncertainty analysis. Individual PAH COIs (other than benzo[a]pyrene) were evaluated using TRVs for total PAHs and benzo(a)pyrene. Individual DDT metabolite and PCB Aroclor COIs were evaluated using TRVs for total DDTs and total PCBs, respectively.

Table 2-27. Selected Dietary-Dose NOAEL TRVs for the Aquatic Bird COPC Screen

Surface Sediment COI	Test Species	NOAEL (mg/kg bw/day)	Endpoint	Source
Metals				
Arsenic	mallard	10	reproduction	Stanley et al. (1994)
Cadmium	mallard	1.5	growth	Cain et al. (1983)
Chromium	black duck	1.0	reproduction	Haseltine et al. (unpublished), as cited in Sample et al. (1996)
Cobalt	chicken	2.31[a]	growth	Diaz et al. (1994)
Copper	chicken	21	growth	Poupoulis and Jensen (1976)
Lead	American kestrel	5.82	reproduction	Pattee (1984)
Mercury	great egret	0.018[b]	growth	Spalding et al. (2000)
Nickel	mallard	77	growth	Cain and Pafford (1981)
Vanadium	chicken	1.2	growth	Ousterhout and Berg (1981)
Zinc	chicken	82	growth	Roberson and Schaible (1960)
PAHs				
Benzo(a)pyrene	pigeon	0.28[b]	reproduction	Hough et al. (1993)
Total PAHs[c]	mallard	8.0	growth	Patton and Dieter (1980)
PCBs				
Total PCBs[d]	screech owl	0.49	reproduction	McLane and Hughes (1980)
Pesticides				
Total DDTs[e]	barn owl	0.064[b]	reproduction	Mendenhall et al. (1983)
VOCs				
Acetone	four species	6,647	survival	Hill et al. (1975)

[a] NOAEL was estimated from an acute or subchronic LOAEL using a UF of 10.

[b] NOAEL was estimated from a chronic LOAEL using a UF of 5.

[c] Individual PAH COIs listed in Table 2-11 (acenaphthylene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, total benzofluoranthenes [benzo(b)fluoranthene and benzo(k)fluoranthene], benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3,-c,d)pyrene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) were evaluated as part of the total PAH sum.

[d] Individual PCB Aroclor COIs listed in Table 2-11 (Aroclor 1254 and Aroclor 1260) were evaluated as part of the total PCB sum.

[e] Individual DDT metabolite COIs listed in Table 2-11 (2,4′-DDD, 4,4′-DDD, and 4,4′-DDE) were evaluated as part of the total DDT sum.

bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
UF – uncertainty factor
VOC – volatile organic compound

Table 2-28. COIs without Aquatic Bird NOAEL TRVs

Surface Sediment COI	
Metals	
Barium	
PAHs	
2-Methylnapthalene	Dibenzofuran
VOCs	
Carbon disulfide	Toluene
Methyl ethyl ketone	
TPH	
TPH-gasoline range	TPH-motor oil range
TPH-diesel range	Total petroleum hydrocarbons

COI – contaminant of interest
NOAEL – no-observed-adverse-effect level
TPH – total petroleum hydrocarbons
TRV – toxicity reference value
VOC – volatile organic compound

Tables 2-29 and 2-30 present the results of the dietary COPC screen for both aquatic bird ROCs. Three COPCs (i.e., mercury, vanadium, and total DDTs) were identified for ruddy duck and two COPCs (i.e., vanadium and total DDTs) were identified for great blue heron. These COPCs are evaluated further in the refined screening step (Section 2.7). Aquatic bird dietary COPCs not eliminated as part of the refined COPC screen (Section 2.7) are further assessed in the wildlife risk assessment for each of these ROCs (Section 5.3).

Table 2-29. Results of the Ruddy Duck Dietary COPC Screen

Surface Sediment COI	Sediment Concentration		BSAF		Prey Tissue Concentration		Estimated Maximum Dose			COPC?
	C_{sed} [a]	Unit	Aquatic Invert BSAF	Unit	$C_{aquat\ invert}$ [b]	Unit	$Dose_{diet}$ [c]	NOAEL TRV	Unit	
Metals										
Arsenic	7	mg/kg dw	0.24	tiss dw/sed dw	0.35	mg/kg ww	0.17	10	mg/kg bw/day	no
Cadmium	2	mg/kg dw	3.438	tiss dw/sed dw	1.4	mg/kg ww	0.51	1.5	mg/kg bw/day	no
Chromium	34	mg/kg dw	0.206	tiss dw/sed dw	1.5	mg/kg ww	0.76	1	mg/kg bw/day	no
Cobalt	15	mg/kg dw	1	tiss dw/sed dw	3.2	mg/kg ww	1.2	2.31	mg/kg bw/day	no
Copper	72	mg/kg dw	2.14	tiss dw/sed dw	32	mg/kg ww	12	21	mg/kg bw/day	no
Lead	56	mg/kg dw	0.331	tiss dw/sed dw	3.9	mg/kg ww	1.7	5.82	mg/kg bw/day	no
Mercury	0.2 J	mg/kg dw	1.204	tiss dw/sed dw	0.051	mg/kg ww	**0.019**	0.018	mg/kg bw/day	**yes**
Nickel	31	mg/kg dw	1.313	tiss dw/sed dw	8.5	mg/kg ww	3.1	77	mg/kg bw/day	no
Vanadium	74	mg/kg dw	1	tiss dw/sed dw	16	mg/kg ww	**6.0**	1.2	mg/kg bw/day	**yes**
Zinc	229	mg/kg dw	3.473	tiss dw/sed dw	170	mg/kg ww	60	82	mg/kg bw/day	no
PAHs										
Benzo(a)pyrene	1.3	mg/kg OC	0.383	tiss lipid/sed OC	6.0	µg/kg ww	2.1	280	µg/kg bw/day	no
Total PAHs	19.8	mg/kg OC	0.923	tiss lipid/sed OC	220	µg/kg ww	76	8,000	µg/kg bw/day	no
PCBs										
Total PCBs	1.83	mg/kg OC	2.57	tiss lipid/sed OC	56	µg/kg ww	19	490	µg/kg bw/day	no
Pesticides										
Total DDTs	3.7	mg/kg OC	5.21	tiss lipid/sed OC	230	µg/kg ww	**79**	64	µg/kg bw/day	**yes**
VOCs										
Acetone	14	mg/kg OC	1	tiss lipid/sed OC	170	µg/kg ww	59	6,647,000	µg/kg bw/day	no

[a] C_{sed} is represented by maximum sediment concentration.

[b] $C_{aquatic\ invert}$ was estimated from C_{sed} (either as a dw concentration or an OC-normalized concentration) and aquatic benthic invertebrate BSAF. When the sediment concentration was dw, the following equation was used:, $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment concentration was OC-normalized, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. $C_{aquatic\ invert}$ was converted to ww assuming a moisture content of 79% or a lipid content of 1.2%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[c] $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-9, and assumption that diet is composed of 100% aquatic invertebrates.

BSAF – biota-sediment accumulation factor
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
NOAEL – no-observed-adverse-effect level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
VOC – volatile organic compound
ww – wet weight

Bold identifies COPCs.

Table 2-30. Results of the Great Blue Heron Dietary COPC Screen

Surface Sediment COI	Sediment Concentration		BSAF			Prey Tissue Concentration			Estimated Maximum Dose			COPC?
	C_{sed} [a]	Unit	Fish BSAF	Aquatic Invert BSAF	Unit	C_{fish} [b]	$C_{aquat\ invert}$ [c]	Unit	$Dose_{diet}$ [d]	NOAEL TRV	Unit	
Metals												
Arsenic	7	mg/kg dw	0.12	0.24	tiss dw/sed dw	0.24	0.35	mg/kg ww	0.05	10	mg/kg bw/day	no
Cadmium	2	mg/kg dw	0.785	3.438	tiss dw/sed dw	0.44	1.4	mg/kg ww	0.09	1.5	mg/kg bw/day	no
Chromium	34	mg/kg dw	0.043	0.206	tiss dw/sed dw	0.41	1.5	mg/kg ww	0.12	1	mg/kg bw/day	no
Cobalt	15	mg/kg dw	1	1	tiss dw/sed dw	4.2	3.2	mg/kg ww	0.76	2.31	mg/kg bw/day	no
Copper	72	mg/kg dw	1	2.14	tiss dw/sed dw	20	32	mg/kg ww	3.8	21	mg/kg bw/day	no
Lead	56	mg/kg dw	0.18	0.331	tiss dw/sed dw	2.8	3.9	mg/kg ww	0.57	5.82	mg/kg bw/day	no
Mercury	0.2 J	mg/kg dw	0.38	1.204	tiss dw/sed dw	0.021	0.051	mg/kg ww	0.0043	0.018	mg/kg bw/day	no
Nickel	31	mg/kg dw	1	1.313	tiss dw/sed dw	8.7	8.5	mg/kg ww	1.6	77	mg/kg bw/day	no
Vanadium	74	mg/kg dw	1	1	tiss dw/sed dw	21	16	mg/kg ww	**3.8**	1.2	mg/kg bw/day	**yes**
Zinc	229	mg/kg dw	1.83	3.473	tiss dw/sed dw	118	167	mg/kg ww	22	82	mg/kg bw/day	no
PAHs												
Benzo(a)pyrene	1.3	mg/kg OC	0.0021	0.383	tiss lipid/ sed OC	0.10	6.0	µg/kg ww	0.072	280	µg/kg bw/day	no
Total PAHs	19.8	mg/kg OC	0.0299	0.923	tiss lipid/ sed OC	22	220	µg/kg ww	5.8	8,000	µg/kg bw/day	no
PCBs												
Total PCBs	1.83	mg/kg OC	6.45	2.57	tiss lipid/ sed OC	440	56	µg/kg ww	76	490	µg/kg bw/day	no
Pesticides												
Total DDTs	3.7	mg/kg OC	3.0	5.21	tiss lipid/ sed OC	410	230	µg/kg ww	**72**	64	µg/kg bw/day	**yes**
VOCs												
Acetone	14	mg/kg OC	1	1	tiss lipid/ sed OC	520	170	µg/kg ww	90	6,647,000	µg/kg bw/day	no

[a] C_{sed} is represented by maximum sediment concentration.

[b] C_{fish} was estimated from C_{sed} (either as a dw concentration or an OC-normalized concentration) and fish BSAF. When the sediment concentration was dw, the following equation was used: C_{fish} (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment concentration was OC-normalized, the following equation was used: Max_{sed} (OC), C_{fish} (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. C_{fish} was converted to ww assuming a moisture content of 72% or a lipid content of 3.7%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[c] $C_{aquatic\ invert}$ was estimated from C_{sed} (either as a dw concentration or an OC-normalized concentration) and aquatic benthic invertebrate BSAF. When the sediment concentration was dw, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture When the sediment concentration was OC-normalized, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. $C_{aquatic\ invert}$ was converted to ww assuming a moisture content of 79% or a lipid content of 1.2%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[d] $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-9, and assumption that diet is composed of 95% fish and 5% aquatic invertebrates.

BSAF – biota-sediment accumulation factor
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
NOAEL –no-observed-adverse-effect level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
VOC – volatile organic compound
ww – wet weight

Bold identifies COPCs.

2.6.5 Terrestrial Birds

This section presents the COPC screen, which is summarized in Figure 2-8, for the terrestrial bird ROC (the red-tailed hawk).

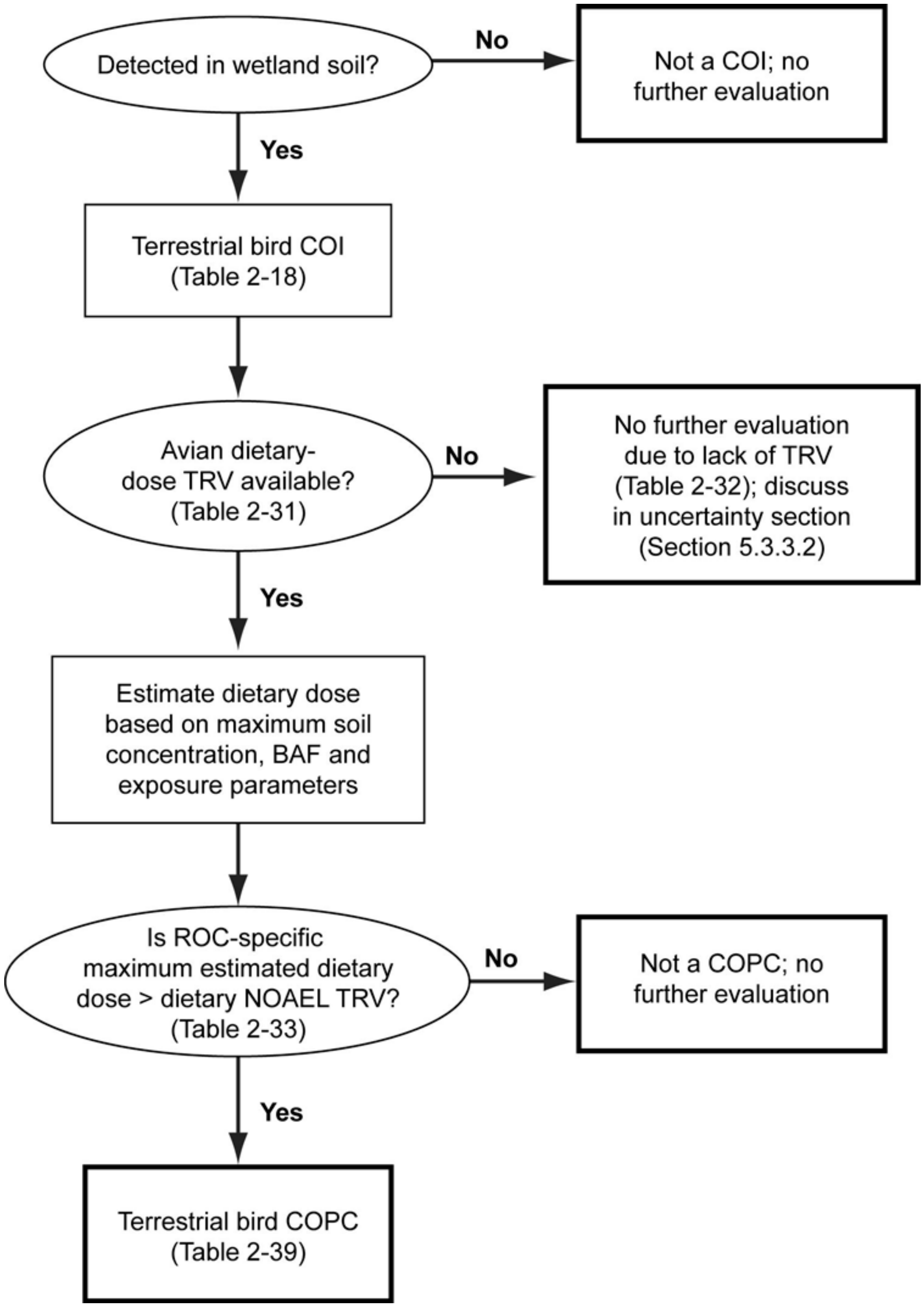


Figure 2-8. COPC Screening Process for Terrestrial Bird ROCs

2.6.5.1 COIs for Terrestrial Birds

The first step in the COPC screen for the terrestrial bird ROC was the identification of COIs. COIs were defined as any analyte detected in wetland soil (see Table 2-18).

2.6.5.2 COPC Screen for Terrestrial Birds

In the next step to identify COPCs for red-tailed hawk, maximum detected COI concentrations in soil and maximum estimated COI concentrations in potential prey items were used to estimate a maximum dietary doses for each COI (see method described in Section 3.2.2). COI concentrations in prey were estimated using biota accumulation factors (BAFs) and assumptions presented in Attachment 2 (Tables 3 and Tables 6 through 9). Maximum dietary doses were then compared to dietary-dose NOAEL TRVs; COIs with maximum doses that were greater than the NOAEL TRVs were identified as COPCs for red-tailed hawk.

NOAEL TRVs, presented in Table 2-31, were identified using the process presented in Section 2.6.3.2. The COIs without available terrestrial bird NOAEL TRVs are presented in Table 2-32; these COIs will be noted in the uncertainty analysis. Individual PAH COIs (other than benzo[a]pyrene) were evaluated using TRVs for total PAHs and benzo(a)pyrene. Individual DDT metabolite and PCB Aroclor COIs were evaluated using TRVs for total DDTs and total PCBs, respectively.

Table 2-31. Selected Dietary-Dose NOAEL TRVs for the Terrestrial Bird COPC Screen

Wetland Soil COI	Test Species	NOAEL (mg/kg bw/day)	Endpoint	Source
Metals				
Aluminum	Japanese quail	157	reproduction, growth	Carriere et al. (1986)
Arsenic	mallard	10	reproduction	Stanley et al. (1994)
Cadmium	mallard	1.5	growth	Cain et al. (1983)
Chromium	black duck	1.0	reproduction	Haseltine et al. (unpublished), as cited in Sample et al. (1996)
Cobalt	chicken	2.31[a]	growth	Diaz et al. (1994)
Copper	chicken	21	growth	Poupoulis and Jensen (1976)
Lead	American kestrel	5.82	reproduction	Pattee (1984)
Mercury	great egret	0.018[b]	growth	Spalding et al. (2000)
Nickel	mallard	77	growth	Cain and Pafford (1981)
Selenium	mallard	0.50	reproduction	Heinz et al. (1987)
Vanadium	chicken	1.2	growth	Ousterhout and Berg (1981)
Zinc	chicken	82	growth	Roberson and Schaible (1960)

Table 2-31. Selected Dietary-Dose NOAEL TRVs for the Terrestrial Bird COPC Screen

Wetland Soil COI	Test Species	NOAEL (mg/kg bw/day)	Endpoint	Source
PAHs				
Benzo(a)pyrene	pigeon	0.28[b]	reproduction	Hough et al. (1993)
Total PAHs[c]	mallard	8.0	growth	Patton and Dieter (1980)
Phthalates				
BEHP	chicken	65.8[d]	reproduction	Ishida et al. (1982)
Butyl benzyl phthalate	chicken	65.8[d]	reproduction	BEHP TRVs
Di-n-butyl phthalate	chicken	65.8[d]	reproduction	BEHP TRVs
Other SVOCs				
Hexachloro-benzene	Japanese quail	1.1	reproduction	Vos et al. (1971)
Pentachlorophenol	chicken	22	growth	Prescott et al. (1982)
PCBs				
Total PCBs[e]	screech owl	0.49	reproduction	McLane and Hughes (1980)
Pesticides				
Total DDTs[f]	barn owl	0.064[g]	reproduction	Mendenhall et al. (1983)
delta-BHC[h]	mallard	1.6[h]	reproduction	Chakravarty and Lahiri (1986); Chakravarty et al. (1986)[i]
Methoxychlor	zebra finch	34.6	reproduction	Gee et al. (2004)[i]
			survival	Millam et al. (2002)[i]
VOCs				
Acetone	four species	6,647	survival	Hill et al. (1975)

a NOAEL was estimated from an acute or subchronic LOAEL using a UF of 10.

b NOAEL was estimated from a chronic LOAEL using a UF of 5.

c Individual PAH COIs listed in Table 2-18 (acenaphthylene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, total benzofluoranthenes [benzo(b)fluoranthene and benzo(k)fluoranthene], benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3,-c,d)pyrene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) were evaluated as part of the total PAH sum.

d There was a NOAEL of 1.45 mg/kg bw/day from a study that reported no effect on eggshell thinning, but this is an unbounded NOAEL at a substantially lower concentration than that in the study with observed effects. Therefore, the NOAEL was estimated from the reproductive LOAEL using a UF of 5.

e Individual PCB Aroclor COIs listed in Table 2-18 (Aroclor 1248, Aroclor 1254, and Aroclor 1260) were evaluated as part of the total PCB sum.

f Individual DDT metabolite COIs listed in Table 2-18 (2,4′-DDD, 2,4′-DDE, 2,4′-DDT, 4,4′-DDD, 4,4′-DDE, and 4,4′-DDT) were evaluated as part of the total DDT sum.

g There was a NOAEL of 0.19 mg/kg bw/day from a study that reported no effect on eggshell thinning from exposure of mallards to DDT (Davison and Sell 1974). However, as discussed in Section 4.3.2, other reproduction endpoints were not assessed in this study, and it is unknown whether the no-effect level for eggshell thinning would be the same as the no-effect level for direct measures (e.g., hatchability, viability of offspring) of reproductive success. Therefore, the NOAEL was estimated from the DDE LOAEL (0.32 mg/kg bw/day) for eggshell thinning and nestling mortality using a factor of 5.

[h] TRVs for delta-BHC were based on TRVs reported for gamma-BHC (lindane).

[i] Both studies had the same LOAEL and NOAEL.

BEHP – bis(2-ethylhexyl) phthalate
BHC – hexachlorocyclohexane
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TRV – toxicity reference value
UF – uncertainty factor
VOC – volatile organic compound

Table 2-32. COIs without Terrestrial Bird NOAEL TRVs

Surface Sediment COI	
Metals	
Antimony	Manganese
Barium	Silver
Beryllium	
PAHs	
2-Methylnaphthalene	Dibenzofuran
Other SVOCs	
1,4-Dichlorobenzene	Benzyl alcohol
4-Methylphenol	Biphenyl
Acetophenone	Carbazole
Benzaldehyde	Phenol
Benzoic acid	
VOCs	
1,2,4-Trimethylbenzene	Methyl isobutyl ketone
Benzene	Tetrachloroethene
Carbon disulfide	Toluene
cis-1,2-Dichloroethene	Trichloroethene
p-Cymene	o-Xylene
Dichloromethane	m,p-Xylene
Ethylbenzene	Total xylenes
Methyl ethyl ketone	
TPH	
TPH-gasoline range	TPH-motor oil range (HCID)
TPH-diesel range (HCID)	TPH-motor oil range
TPH-diesel range	Total petroleum hydrocarbons

COI – contaminant of interest
NOAEL – no-observed-adverse-effect level
HCID – hydrocarbon identification
PAH – polycyclic aromatic hydrocarbon
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
TRV – toxicity reference value
VOC – volatile organic compound

Table 2-33 presents the results of the dietary COPC screen for red-tailed hawk. Two COPCs (i.e., aluminum and total DDTs) were identified. These COPCs are evaluated further in the refined screening step (Section 2.7). Terrestrial bird dietary COPCs not eliminated as part of the refined COPC screen (Section 2.7) are further assessed in the wildlife risk assessment for this ROC (Section 5.3).

Table 2-33. Results of the Red-Tailed Hawk Dietary COPC Screen

	Soil Concentration		BAF		Prey Tissue Concentration		Estimated Maximum Dose			
Wetland Soil COI	C_{soil}[a]	Unit (dw)	Mammal BAF	Unit	C_{mammal}[b]	Unit (ww)	$Dose_{diet}$[c]	NOAEL TRV	Unit	COPC?
Metals										
Aluminum	12,100	mg/kg	1	tiss dw/sed dw	3900	mg/kg	**390**	157	mg/kg bw/day	**yes**
Arsenic	53.1	mg/kg	0.0063	tiss dw/sed dw	0.11	mg/kg	0.028	10	mg/kg bw/day	no
Cadmium	4	mg/kg	1.9902	tiss dw/sed dw	2.5	mg/kg	0.25	1.5	mg/kg bw/day	no
Chromium	149	mg/kg	0.1382	tiss dw/sed dw	6.6	mg/kg	0.7	1	mg/kg bw/day	no
Cobalt	34.3	mg/kg	0.0371	tiss dw/sed dw	0.41	mg/kg	0.051	2.31	mg/kg bw/day	no
Copper	1,240 J	mg/kg	0.42	tiss dw/sed dw	170	mg/kg	17	21	mg/kg bw/day	no
Lead	320	mg/kg	0.1615	tiss dw/sed dw	17	mg/kg	1.8	5.82	mg/kg bw/day	no
Mercury	0.4	mg/kg	0.1244	tiss dw/sed dw	0.016	mg/kg	0.0017	0.018	mg/kg bw/day	no
Nickel	48	mg/kg	0.2799	tiss dw/sed dw	4.3	mg/kg	0.44	77	mg/kg bw/day	no
Selenium	1.1	mg/kg	0.3464	tiss dw/sed dw	0.12	mg/kg	0.012	0.5	mg/kg bw/day	no
Vanadium	148	mg/kg	0.0123	tiss dw/sed dw	0.58	mg/kg	0.10	1.2	mg/kg bw/day	no
Zinc	748	mg/kg	1.3352	tiss dw/sed dw	320	mg/kg	32	82	mg/kg bw/day	no
PAHs										
Benzo(a)pyrene	4,000	µg/kg	0.001	tiss dw/sed dw	1.3	µg/kg	1.4	280	µg/kg bw/day	no
Total PAHs	69,000	µg/kg	0.001	tiss dw/sed dw	22	µg/kg	24	8,000	µg/kg bw/day	no
Phthalates										
BEHP	9,100	µg/kg	1	tiss dw/sed dw	2,900	µg/kg	290	65,800	µg/kg bw/day	no
Butyl benzyl phthalate	3,140 J	µg/kg	1	tiss dw/sed dw	1,000	µg/kg	100	65,800	µg/kg bw/day	no
Di-n-butyl phthalate	2,400	µg/kg	1	tiss dw/sed dw	770	µg/kg	77	65,800	µg/kg bw/day	no
Other SVOCs										
Hexachlorobenzene	42	µg/kg	1	tiss dw/sed dw	13	µg/kg	1.3	1,100	µg/kg bw/day	no
Pentachlorophenol	80 J	µg/kg	1	tiss dw/sed dw	26	µg/kg	2.6	22,000	µg/kg bw/day	no
PCBs										
Total PCBs	4,200	µg/kg	0.45	tiss-ww/sed dw	1,900	µg/kg	190	490	µg/kg bw/day	no

Table 2-33. Results of the Red-Tailed Hawk Dietary COPC Screen

Wetland Soil COI	Soil Concentration		BAF		Prey Tissue Concentration		Estimated Maximum Dose			COPC?
	C_{soil} [a]	Unit (dw)	Mammal BAF	Unit	C_{mammal} [b]	Unit (ww)	$Dose_{diet}$ [c]	NOAEL TRV	Unit	
Pesticides										
Total DDTs	46,000	µg/kg	C_{mammal} = ([C_{plant} x 0.75]+[C_{invert} x 0.25]) x 4.83[d]	tiss dw/sed dw	200,000[d]	µg/kg	**20,000**	64	µg/kg bw/day	**yes**
delta-BHC	3	µg/kg	0.157	tiss dw/sed dw	0.15	µg/kg	0.016	1,600	µg/kg bw/day	no
Methoxychlor	4.6 J	µg/kg	1	tiss dw/sed dw	1.5	µg/kg	0.15	34,600	µg/kg bw/day	no
VOCs										
Acetone	2,300	µg/kg	1	tiss dw/sed dw	740	µg/kg	74	6,647,000	µg/kg bw/day	no

[a] C_{soil} is represented by maximum soil concentration.

[b] C_{mammal} was estimated from C_{soil} and a mammal BAF and converted to ww assuming percent moisture of 68%. C_{mammal} (ww) = [BAF(dw/dw) x Max_{soil}] x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BAFs and assumptions used to estimate prey tissue concentrations.

[c] $Dose_{diet}$ was calculated using Equation 3-5, exposure parameters presented in Table 3-9, and assumption that diet is composed of 100% terrestrial small mammals.

[d] C_{mammal} was calculated using BAF regression, where C_{plant} = 261 µg/kg dw and C_{invert} = 515,200 µg/kg dw.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – hexachlorocyclohexane
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
NOAEL – no-observed-adverse-effect level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TRV – toxicity reference value
VOC – volatile organic compound
ww – wet weight

Bold identifies COPCs.

2.6.6 Terrestrial Mammals

This section presents the COPC screen, which is summarized in Figure 2-9 for the terrestrial mammal ROCs (Eastern cottontail and shrew).

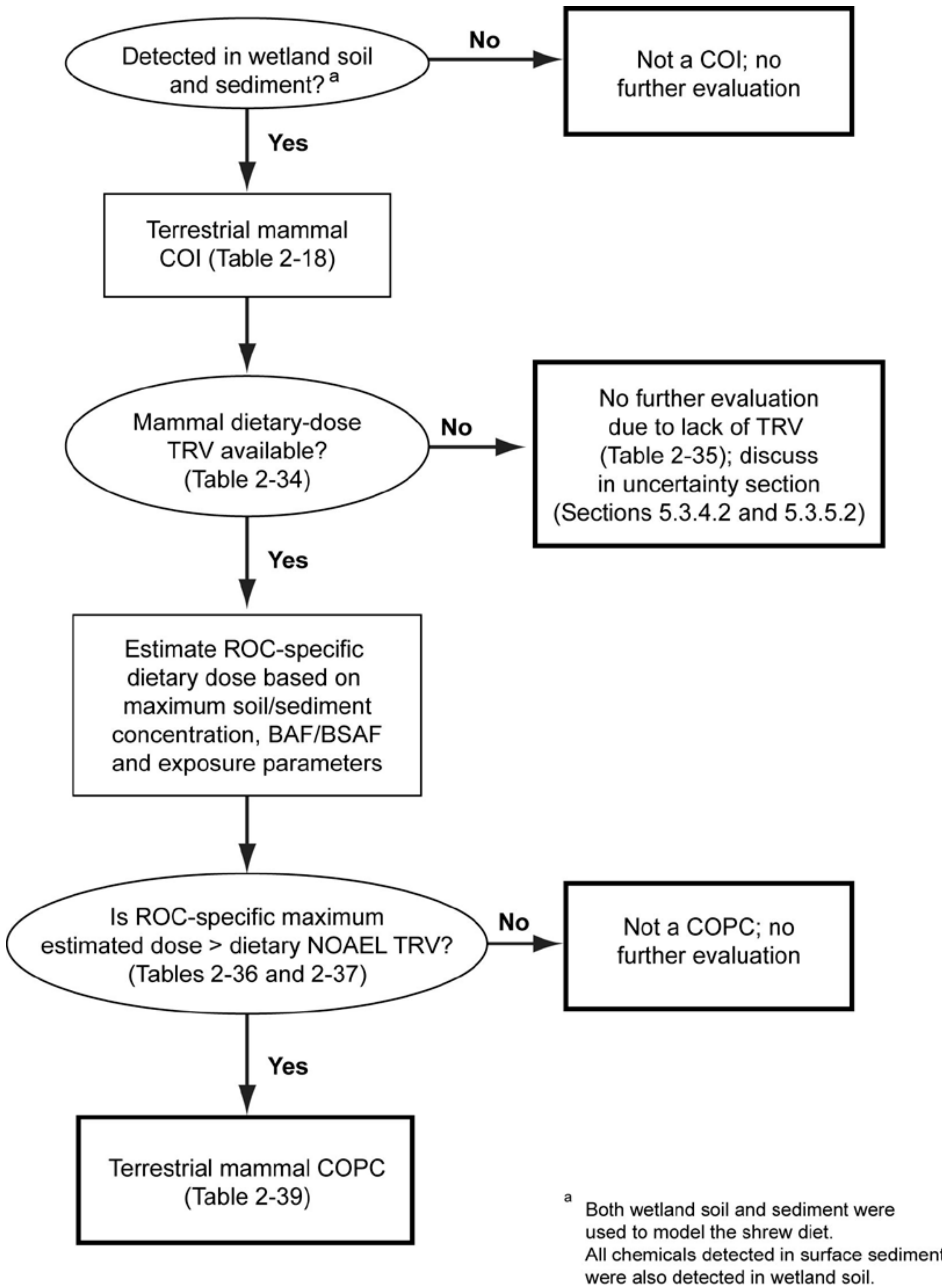


Figure 2-9. COPC Screening Process for Terrestrial Mammal ROCs

2.6.6.1 COIs for Terrestrial Mammals

The first step in the COPC screen for terrestrial mammals was the identification of COIs. COIs were defined as any analyte detected in wetland soil[19] (see Table 2-18).

2.6.6.2 COPC Screen for Terrestrial Mammals

In the next step to identify COPCs for terrestrial mammal ROCs, maximum detected COI concentrations in sediment and soil[20] and maximum estimated COI concentrations in potential prey items were used to estimate a ROC-specific maximum dietary dose (see method described in Section 3.2.2). COI concentrations in prey were estimated using BSAFs and BAFs and assumptions presented in Attachment 2 (Tables 1 though 9). Maximum dietary doses were then compared to dietary-dose NOAEL TRVs for mammals; COIs with maximum doses that were greater than the TRVs were identified as COPCs for the ROC.

NOAEL TRVs were identified using the process presented in Section 2.6.3.2, with one exception: allometric equations based on laboratory data were used to estimate the ingestion rate for mammals (EPA 1988).

Selected NOAEL TRVs for mammals are presented in Table 2-34. Individual PAH COIs (other than benzo[a]pyrene, naphthalene, and 2-methylnaphthalene) were evaluated using TRVs for benzo(a)pyrene and total PAHs. Individual DDT metabolite and PCB Aroclor COIs were evaluated using TRVs for total DDTs and total PCBs, respectively. The COIs for which no mammal dietary-dose TRV could be developed are presented in Table 2-35; these COIs are noted in the uncertainty analysis.

Table 2-34. Selected Dietary-Dose NOAEL TRVs for the Terrestrial Mammal COPC Screen

Wetland Soil COI	Test Species	NOAEL (mg/kg bw/day)	Endpoint	Source
Metals				
Aluminum	mouse	34.3	reproduction, growth	Ondreicka et al. (1966)
Antimony	rat	1,489	growth, survival	Hext et al. (1999)
Arsenic	rat	2.6	growth	Byron et al. (1967)
Cadmium	rat	3.5	growth	Machemer and Lorke (1981)
Chromium	rat	1,466	growth, survival	Ivankovic and Preussman (1975)
Cobalt	rat	0.1[a]	growth	Chetty et al. (1979)
Copper	mink	18	reproduction	Aulerich et al. (1982)
Lead	rat	11	growth	Azar et al. (1973)
Mercury	rat	0.0017[b]	growth	Verschuuren et al. (1976)

[19] Both wetland soil and sediment were used to model the shrew diet, which consists of both terrestrial and aquatic prey. All chemicals detected in sediment (Table 2-11) were also detected in soil (Table 2-18).

[20] Both wetland soil and sediment were used to model the shrew diet, which consists of both terrestrial and aquatic prey.

Table 2-34. Selected Dietary-Dose NOAEL TRVs for the Terrestrial Mammal COPC Screen

Wetland Soil COI	Test Species	NOAEL (mg/kg bw/day)	Endpoint	Source
Nickel	rat	na	reproduction	Ambrose et al. (1976)
	rat	8.4	growth	
Selenium	rat	0.055	growth	Halverson et al. (1966)
Vanadium	rat	0.27[a]	growth	Adachi et al. (2000)
Zinc	rat	160	reproduction	Schlicker and Cox (1968)
PAHs				
2-Methylnaphthalene	mouse	54	growth	Murata et al. (1997)
Benzo(a)pyrene	mouse	2.0[b]	reproduction	MacKenzie and Angevine (1981)
Naphthalene	mouse	133	growth, survival	Shopp et al. (1984)
Total PAHs[c]	mouse	2.0[b]	reproduction	benzo(a)pyrene TRVs
Phthalates				
BEHP	mouse	44	reproduction	Tyl et al. (1988)
Butyl benzyl phthalate	rat	250	growth, reproduction	Tyl et al. (2004)
Di-n-butyl phthalate	rat	16[b]	reproduction	Wine et al. (1997)
Other SVOCs				
Benzoic acid	rat	80	growth, survival	Ignat'ev (1965), as cited in IRIS (EPA 2006)
Biphenyl	rat	50	survival	Ambrose et al. (1960), as cited in IRIS (EPA 2006)
Hexachlorobenzene	mink and ferret	0.026[b]	reproduction	Bleavins et al. (1984)
Phenol	rat	60	growth	Argus Research Laboratories (1997), as cited in IRIS (EPA 2006)[d]
	rat	60	reproduction	Charles River Laboratories (1988) and NTP (1983), as cited in IRIS (EPA 2006)[d]
PCBs				
Total PCBs[e]	mink	0.045[f]	reproduction	Brunstrom et al. (2001)
Pesticides				
delta-BHC[g]	rat	5.7[g]	growth, survival	Van Velsen et al. (1986)
Total DDTs[h]	rat	1.2	reproduction	Duby et al. (1971)
Methoxychlor	rat	17	growth, reproduction	Masutomi et al. (2003)
VOCs				
Acetone	rat	1,650	growth	Dietz et al. (1991)
Ethylbenzene	rat	250	growth	Mellert et al. (2007)

[a] NOAEL was estimated from an acute or subchronic LOAEL using a UF of 10.

[b] NOAEL was estimated from an chronic LOAEL using a UF of 5.

[c] Individual PAH COIs listed in Table 2-18 (acenaphthylene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, total benzofluoranthenes [benzo(b)fluoranthene and benzo(k)fluoranthene], benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3,-c,d)pyrene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) were evaluated as part of the total PAH sum.

[d] Both studies had the same LOAEL and NOAEL.

[e] Individual PCB Aroclor COIs listed in Table 2-18 (Aroclor 1248, Aroclor 1254, and Aroclor 1260) were evaluated as part of the total PCB sum.

[f] NOAEL was estimated from a chronic LOAEL using a UF of 2; the rationale for using this UF is discussed in Section 4.4.

[g] TRVs for delta-BHC are based on TRVs reported for beta-BHC.

[h] Individual DDT metabolite COIs listed in Table 2-18 (2,4′-DDD, 2,4′-DDE, 2,4′-DDT, 4,4′-DDD, 4,4′-DDE, and 4,4′-DDT,) were evaluated as part of the total DDT sum.

BEHP – bis(2-ethylhexyl) phthalate
BHC – hexachlorocyclohexane
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
IRIS – Integrated Risk Information System
LOAEL – lowest-observed-adverse-effect level
na – not available
NOAEL – no-observed-adverse-effect level
ns – not selected (NOAEL or LOAEL was not selected from this study)
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TRV – toxicity reference value
UF – uncertainty factor
VOC – volatile organic compound

Table 2-35. COIs without Mammal NOAEL TRVs

Wetland Soil COI	
Metals	
Barium	Manganese
Beryllium	Silver
PAHs	
Dibenzofuran	
Other SVOCs	
1,4-Dichlorobenzene	Benzyl alcohol
4-Methylphenol	Carbazole
Acetophenone	Pentachlorophenol
Benzaldehyde	
VOCs	
1,2,4-Trimethylbenzene	Methyl isobutyl ketone
Benzene	Tetrachloroethene
Carbon disulfide	Toluene
cis-1,2-Dichloroethene	Trichloroethene
p-Cymene	o-Xylene
Dichloromethane	m,p-Xylene
Methyl ethyl ketone	Total xylenes
TPH	
TPH-gasoline range	TPH-motor oil range (HCID)
TPH-diesel range (HCID)	TPH-motor oil range
TPH-diesel range	Total petroleum hydrocarbons

COI – contaminant of interest
HCID – hydrocarbon identification
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbons
VOC – volatile organic compound

Tables 2-36 and 2-37 present the results of the COPC screen for Eastern cottontail and shrew. Seven COPCs (i.e., aluminum, cobalt, copper, mercury, selenium, vanadium, and total PAHs) were identified for Eastern cottontail and fourteen COPCs (i.e., aluminum, arsenic, cadmium, cobalt, copper, lead, mercury, nickel, selenium, vanadium, zinc, total PAHs, total PCBs, and total DDTs) were identified for shrew. These COPCs are evaluated further in the refined screening step (Section 2.7). Mammal COPCs not eliminated as part of the refined COPC screen (Section 2.7) are further assessed in the wildlife risk assessment for these ROCs (Section 5.3).

Table 2-36. Results of the Eastern Cottontail Dietary COPC Screen

	Soil Concentration		BAF		Prey Tissue Concentration		Estimated Maximum Dose			
Wetland Soil COI	C_{soil} [a]	Unit (dw)	Plant BAF	Unit	C_{plant} [b]	Unit (ww)	$Dose_{diet}$ [c]	NOAEL TRV	Unit	COPC?
Metals										
Aluminum	12,100	mg/kg	1	tiss dw/ sed dw	2,500	mg/kg	**530**	34.3	mg/kg bw/day	**yes**
Antimony	8.4 J	mg/kg	$C_{plant} = e^{(0.938*LN(Csoil)-3.233)}$	tiss dw/ sed dw	0.061	mg/kg	0.034	1,489	mg/kg bw/day	no
Arsenic	53.1	mg/kg	0.454	tiss dw/ sed dw	5.1	mg/kg	1.1	2.6	mg/kg bw/day	no
Cadmium	4	mg/kg	1.359	tiss dw/ sed dw	1.1	mg/kg	0.23	3.5	mg/kg bw/day	no
Chromium	149	mg/kg	0.041	tiss dw/ sed dw	1.3	mg/kg	0.65	1466	mg/kg bw/day	no
Cobalt	34.3	mg/kg	0.0075	tiss dw/ sed dw	0.054	mg/kg	**0.10**	0.1	mg/kg bw/day	**yes**
Copper	1,240 J	mg/kg	0.341	tiss dw/ sed dw	89	mg/kg	**21**	18	mg/kg bw/day	**yes**
Lead	320	mg/kg	0.245	tiss dw/ sed dw	16	mg/kg	4.0	11	mg/kg bw/day	no
Mercury	0.4	mg/kg	1.481	tiss dw/ sed dw	0.12	mg/kg	**0.025**	0.0017	mg/kg bw/day	**yes**
Nickel	48	mg/kg	0.749	tiss dw/ sed dw	7.5	mg/kg	1.6	8.4	mg/kg bw/day	no
Selenium	1.1	mg/kg	2.253	tiss dw/ sed dw	0.52	mg/kg	**0.11**	0.055	mg/kg bw/day	**yes**
Vanadium	148	mg/kg	0.00485	tiss dw/ sed dw	0.15	mg/kg	0.42	0.27	mg/kg bw/day	**yes**
Zinc	748	mg/kg	1.021	tiss dw/ sed dw	160	mg/kg	34	160	mg/kg bw/day	no
PAHs										
2-Methylnaphthalene	2,880	mg/kg	12.2	tiss dw/ sed dw	7,400	µg/kg	1,500	54,000	µg/kg bw/day	no
Benzo(a)pyrene	4,000	mg/kg	$C_{plant} = e^{(0.975*LN(Csoil)-2.0615)}$	tiss dw/ sed dw	87	µg/kg	28	2,000	µg/kg bw/day	no

Table 2-36. Results of the Eastern Cottontail Dietary COPC Screen

Wetland Soil COI	Soil Concentration		BAF		Prey Tissue Concentration		Estimated Maximum Dose			COPC?
	C_{soil} [a]	Unit (dw)	Plant BAF	Unit	C_{plant} [b]	Unit (ww)	$Dose_{diet}$ [c]	NOAEL TRV	Unit	
Naphthalene	4,210	mg/kg	12.2	tiss dw/ sed dw	11,000	µg/kg	2,200	133,000	µg/kg bw/day	no
Total PAHs	69,000	mg/kg	6.15	tiss dw/ sed dw	89,000	µg/kg	**18,000**	2,000	µg/kg bw/day	**yes**
Phthalates										
BEHP	9,100	µg/kg	0.00179	tiss dw/ sed dw	3.4	µg/kg	24	44,000	µg/kg bw/day	no
Butyl benzyl phthalate	3,140 J	µg/kg	0.00179	tiss dw/ sed dw	1.2	µg/kg	8.4	250,000	µg/kg bw/day	no
Di-n-butyl phthalate	2,400	µg/kg	0.128	tiss dw/ sed dw	65	µg/kg	19	16,000	µg/kg bw/day	no
Other SVOCs										
Benzoic acid	28,000	µg/kg	1	tiss dw/ sed dw	5,900	µg/kg	1,200	80,000	µg/kg bw/day	no
Biphenyl	836 J	µg/kg	1	tiss dw/ sed dw	180	µg/kg	38	50,000	µg/kg bw/day	no
Hexachlorobenzene	42	µg/kg	0.0189	tiss dw/ sed dw	0.17	µg/kg	0.14	26	µg/kg bw/day	no
Phenol	498 J	µg/kg	5.55	tiss dw/ sed dw	580	µg/kg	120	60,000	µg/kg bw/day	no
PCBs										
Total PCBs	4,200	µg/kg	0.00519	tiss dw/ sed dw	4.6	µg/kg	12	45	µg/kg bw/day	no
Pesticides										
Total DDTs	46,000	µg/kg	$C_{plant} = e^{(0.7524*LN(Csoil)-2.5119)}$	tiss dw/ sed dw	55	µg/kg	130	1,200	µg/kg bw/day	no
delta-BHC	3	µg/kg	0.157	tiss dw/ sed dw	0.099	µg/kg	0.027	5,700	µg/kg bw/day	no
Methoxychlor	4.6 J	µg/kg	0.0585	tiss dw/ sed dw	0.057	µg/kg	0.023	17,000	µg/kg bw/day	no
VOCs										
Acetone	2,300	µg/kg	53.3	tiss dw/ sed dw	26,000	µg/kg	5,100	1,650,000	µg/kg bw/day	no

Table 2-36. Results of the Eastern Cottontail Dietary COPC Screen

Wetland Soil COI	Soil Concentration		BAF		Prey Tissue Concentration		Estimated Maximum Dose			COPC?
	C_{soil}[a]	Unit (dw)	Plant BAF	Unit	C_{plant}[b]	Unit (ww)	$Dose_{diet}$[c]	NOAEL TRV	Unit	
Ethylbenzene	3.4	µg/kg	0.348	tiss dw/ sed dw	0.25	µg/kg	0.058	250,000	µg/kg bw/day	no

[a] C_{soil} is represented by maximum soil concentration.

[b] C_{plant} was estimated from C_{soil} and a plant BAF and converted to ww assuming percent moisture of 79%. C_{plant} (ww) = [BAF(dw/dw) x Max_{soil}] x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BAFs and assumptions used to estimate prey tissue concentrations.

[c] $Dose_{diet}$ was calculated using Equation 3-5, exposure parameters presented in Table 3-9, and assumption that diet is composed of 100% terrestrial plants.

[a] C_{soil} is represented by maximum soil concentration.

[b] C_{plant} was estimated from C_{soil} and a plant BAF and converted to ww assuming percent moisture of 79%. C_{plant} (ww) = [BAF(dw/dw) x Max_{soil}] x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BAFs and assumptions used to estimate prey tissue concentrations.

[c] $Dose_{diet}$ was calculated using Equation 3-5, exposure parameters presented in Table 3-9, and assumption that diet is composed of 100% terrestrial plants.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – hexachlorocyclohexane
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
LN – natural logarithm
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TRV – toxicity reference value
VOC – volatile organic compound
ww – wet weight

Bold identifies COPCs.

Table 2-37. Results of the Shrew Dietary COPC Screen

Wetland Soil COI	Soil Concentration		Sediment Concentration		BSAF		BAF		Prey Tissue Concentration			Estimated Maximum Dose			COPC?
	C_{soil} [a]	Unit	C_{sed} [b]	Unit	Aquatic Invert BSAF	Unit	Invert BAF	Unit	$C_{aquat\ invert}$ [c]	C_{invert} [d]	Unit	$Dose_{diet}$ [e]	NOAEL TRV	Unit	
Metals															
Aluminum	12,100	mg/kg dw	na[f]	na	1	tiss dw/sed dw	1	tiss dw/ sed dw	na	3,500	mg/kg ww	**2,200**[g]	34.3	mg/kg bw/day	**yes**
Antimony	8.4 J	mg/kg dw	1 U[h]	mg/kg dw	1	tiss dw/ sed dw	1	tiss dw/ sed dw	0.21	2.4	mg/kg ww	1.2	1,489	mg/kg bw/day	no
Arsenic	53.1	mg/kg dw	7	mg/kg dw	0.24	tiss dw/ sed dw	0.258	tiss dw/ sed dw	0.35	4.0	mg/kg ww	**2.7**	2.6	mg/kg bw/day	**yes**
Cadmium	4	mg/kg dw	2	mg/kg dw	3.438	tiss dw/ sed dw	17.105	tiss dw/ sed dw	1.4	20	mg/kg ww	**8.2**	3.5	mg/kg bw/day	**yes**
Chromium	149	mg/kg dw	34	mg/kg dw	0.206	tiss dw/ sed dw	1.099	tiss dw/ sed dw	1.5	47	mg/kg ww	22	1,466	mg/kg bw/day	no
Cobalt	34.3	mg/kg dw	15	mg/kg dw	1	tiss dw/ sed dw	0.122	tiss dw/ sed dw	3.2	1.2	mg/kg ww	**1.7**	0.1	mg/kg bw/day	**yes**
Copper	1,240 J	mg/kg dw	72	mg/kg dw	2.14	tiss dw/ sed dw	0.754	tiss dw/ sed dw	32	270	mg/kg ww	**140**	18	mg/kg bw/day	**yes**
Lead	320	mg/kg dw	56	mg/kg dw	0.331	tiss dw/ sed dw	3.342	tiss dw/ sed dw	3.9	310	mg/kg ww	**130**	11	mg/kg bw/day	**yes**
Mercury	0.4	mg/kg dw	0.2 J	mg/kg dw	1.204	tiss dw/ sed dw	5.231	tiss dw/ sed dw	0.051	0.61	mg/kg ww	**0.26**	0.0017	mg/kg bw/day	**yes**
Nickel	48	mg/kg dw	31	mg/kg dw	1.313	tiss dw/ sed dw	1.656	tiss dw/ sed dw	8.5	23	mg/kg ww	**11**	8.4	mg/kg bw/day	**yes**
Selenium	1.1	mg/kg dw	4 U[h]	mg/kg dw	1	tiss dw/ sed dw	1.798	tiss dw/ sed dw	0.84	0.57	mg/kg ww	**0.39**	0.055	mg/kg bw/day	**yes**
Vanadium	148	mg/kg dw	74	mg/kg dw	1	tiss dw/ sed dw	0.042	tiss dw/ sed dw	16	1.8	mg/kg ww	**6.5**	0.27	mg/kg bw/day	**yes**
Zinc	748	mg/kg dw	229	mg/kg dw	3.473	tiss dw/ sed dw	5.766	tiss dw/ sed dw	170	1,300	mg/kg ww	**550**	160	mg/kg bw/day	**yes**
PAHs															
2-Methylnaphthalene	2,880	µg/kg dw	0.61	mg/kg OC	3.19	tiss lipid/ sed OC	4.4	tiss dw/ sed dw	23	3,700	µg/kg ww	1,500	54,000	µg/kg bw/day	no

Table 2-37. Results of the Shrew Dietary COPC Screen

Wetland Soil COI	Soil Concentration		Sediment Concentration		BSAF		BAF		Prey Tissue Concentration			Estimated Maximum Dose			COPC?
	C_{soil} [a]	Unit	C_{sed} [b]	Unit	Aquatic Invert BSAF	Unit	Invert BAF	Unit	$C_{aquat\ invert}$ [c]	C_{invert} [d]	Unit	$Dose_{diet}$ [e]	NOAEL TRV	Unit	
Benzo(a)pyrene	4,000	µg/kg dw	1.3	mg/kg OC	0.383	tiss lipid/ sed OC	1.33	tiss dw/ sed dw	6.0	1,500	µg/kg ww	670	2,000	µg/kg bw/day	no
Naphthalene	4,210	µg/kg dw	1.2	mg/kg OC	0.588	tiss lipid/ sed OC	4.4	tiss dw/ sed dw	8.5	5400	µg/kg ww	2,200	133,000	µg/kg bw/day	no
Total PAHs	69,000	µg/kg dw	19.8	mg/kg OC	0.923	tiss lipid/ sed OC	2.87	tiss dw/ sed dw	220	57,000	µg/kg ww	**24,000**	2,000	µg/kg bw/day	**yes**
Phthalates															
BEHP	9,100	µg/kg dw	na[f]	na	7.75	na	1	tiss dw/ sed dw	na	2,600	µg/kg ww	1,600[g]	44,000	µg/kg bw/day	no
Butyl benzyl phthalate	3,140 J	µg/kg dw	na[f]	na	7.75	na	1	tiss dw/ sed dw	na	910	µg/kg ww	580[g]	250,000	µg/kg bw/day	no
Di-n-butyl phthalate	2,400	µg/kg dw	na[f]	na	7.75	na	1	tiss dw/ sed dw	na	700	µg/kg ww	440[g]	16,000	µg/kg bw/day	no
Other SVOCs															
Benzoic acid	28,000	µg/kg dw	na[f]	na	na	na	1	tiss dw/ sed dw	na	8,100	µg/kg ww	5,100[g]	80,000	µg/kg bw/day	no
Biphenyl	836 J	µg/kg dw	na[f]	na	na	na	1	tiss dw/ sed dw	na	240	µg/kg ww	150[g]	50,000	µg/kg bw/day	no
Hexachlorobenzene	42	µg/kg dw	0.17 U[h,i]	mg/kg OC	1	tiss lipid/ sed OC	1	tiss dw/ sed dw	2.0	12	µg/kg ww	5.9	26	µg/kg bw/day	no
Phenol	498 J	µg/kg dw	na[f]	na	1	na	1	tiss dw/ sed dw	na	140	µg/kg ww	89[g]	60,000	µg/kg bw/day	no
PCBs															
Total PCBs	4,200	µg/kg dw	1.83	mg/kg OC	2.57	tiss lipid/ sed OC	8.91	tiss dw/ sed dw	56	11,000	µg/kg ww	**4,400**	45	µg/kg bw/day	**yes**
Pesticides															
Total DDTs	46,000	µg/kg dw	3.7	mg/kg OC	5.21	tiss lipid/ sed OC	11.2	tiss dw/ sed dw	230	150,000	µg/kg ww	**60,000**	1,200	µg/kg bw/day	**yes**
delta-BHC	3	µg/kg dw	0.17 U[h,i]	mg/kg OC	1	tiss lipid/ sed OC	1	tiss dw/ sed dw	2.0	0.87	µg/kg ww	0.74	5,700	µg/kg bw/day	no

Table 2-37. Results of the Shrew Dietary COPC Screen

Wetland Soil COI	Soil Concentration		Sediment Concentration		BSAF		BAF		Prey Tissue Concentration			Estimated Maximum Dose			COPC?
	C_{soil} [a]	Unit	C_{sed} [b]	Unit	Aquatic Invert BSAF	Unit	Invert BAF	Unit	$C_{aquat\ invert}$ [c]	C_{invert} [d]	Unit	$Dose_{diet}$ [e]	NOAEL TRV	Unit	
Methoxychlor	4.6 J	µg/kg dw	1.7 U[h,i]	mg/kg OC	1	tiss lipid/ sed OC	1	tiss dw/ sed dw	20	1.3	µg/kg ww	4.0	17,000	µg/kg bw/day	no
VOCs															
Acetone	2,300	µg/kg dw	14	mg/kg OC	1	tiss lipid/ sed OC	1	tiss dw/ sed dw	170	370	µg/kg ww	341	1,650,000	µg/kg bw/day	no
Ethylbenzene	3.4	µg/kg dw	0.12 U[h,i]	mg/kg OC	1	tiss lipid/ sed OC	1	tiss dw/ sed dw	1.4	0.99	µg/kg ww	0.70	250,000	µg/kg bw/day	no

a C_{soil} is represented by maximum soil concentration.

b C_{sed} is represented by maximum sediment concentration.

c $C_{aquatic\ invert}$ was estimated from C_{sed} (either as a dw concentration or an OC-normalized concentration) and an aquatic benthic invertebrate BSAF. When the sediment concentration was dw, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment concentration was OC-normalized, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x Max_{sed}) x F_L, where F_L = fraction lipid. $C_{aquatic\ invert}$ was converted to ww assuming a moisture content of 79% or a lipid content of 1.2%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

d C_{invert} was estimated from C_{soil} and an invertebrate BAF and converted to ww assuming a moisture content of 71%. C_{invert} (ww) = [BAF(dw/dw) x Max_{soil}] x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BAFs and assumptions used to estimate prey tissue concentrations.

e $Dose_{diet}$ was calculated using Equations 3-1 and 3-5, exposure parameters presented in Table 3-9, and assumption that diet is composed of 70% (30% earthworms and 40% terrestrial invertebrates) and 30% aquatic invertebrates.

f Chemical was not analyzed in sediment.

g $Dose_{diet}$ estimated assuming 100% terrestrial prey (because no sediment data available to model aquatic prey).

h C_{sed} is represented by maximum RL (chemical not detected in sediment).

i Maximum RL was converted into mg/kg OC using the average sediment OC measured in Force Lake (7.1%).

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – hexachlorocyclohexane
BSAF – biota-sediment accumulation factor
bw – body weight
COI – contaminant of interest
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
na – not available
NOAEL – no observed adverse effect level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TRV – toxicity reference value
U – concentration was not detected
VOC – volatile organic compound
ww – wet weight

Bold identifies COPCs.

2.6.7 Summary of COPCs

Table 2-38 presents all COPCs for aquatic benthic and terrestrial invertebrates. Table 2-39 identifies the ROC-COPC pairs for all fish and wildlife COPCs.

Table 2-38. Summary of Invertebrate COPCs

COPC	Aquatic Benthic Invertebrate COPC[a]	Terrestrial Invertebrate COPC[b]
Metals		
Aluminum		X
Arsenic	X	
Barium	X	X
Cadmium	X	
Chromium		X
Copper	X	X
Lead	X	
Manganese		X
Mercury	X	X
Nickel	X	
Zinc	X	X
PAHs		
Benzo(a)anthracene	X	
Benzo(a)pyrene	X	
Chrysene	X	
Fluoranthene	X	
Phenanthrene	X	
Pyrene	X	
Total HPAHs		X
PCBs		
Total PCBs	X	
Pesticides		
2,4′-DDD	X	
4,4′-DDD	X	
4,4′-DDE	X	
Total DDTs	X	

[a] Aquatic benthic invertebrate COPCs based on screening of sediment and surface water as presented in Tables 2-15 and 2-17, respectively.

[b] Terrestrial invertebrate COPCs based on screening of soils as presented in Table 2-21.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

Table 2-39. Summary of Fish and Wildlife ROC-COPC Pairs

COPC	Aquatic ROCs				Terrestrial ROCs		
	Pumpkin-seed[a]	Brown Bullhead[b]	Ruddy Duck[c]	Great Blue Heron[d]	Red-Tailed Hawk[e]	Eastern Cotton-tail[f]	Shrew[g]
Metals							
Aluminum					X	X	X
Arsenic							X
Barium	X	X					
Cadmium	X	X					X
Cobalt						X	X
Copper	X	X				X	X
Lead							X
Mercury			X			X	X
Nickel							X
Selenium						X	X
Vanadium	X	X	X	X		X	X
Zinc							X
PAHs							
Total PAHs						X	X
PCBs							
Total PCBs	X	X					X
Pesticides							
Total DDTs			X	X	X		X

[a] COPCs based on screening of surface water, fish tissue, and ROC-specific diet, as presented in Tables 2-17, 2-23, and 2-25, respectively.
[b] COPCs based on screening of surface water, fish tissue, and ROC-specific diet, as presented in Tables 2-17, 2-23, and 2-26, respectively.
[c] COPCs based on screening of ROC-specific diet, as presented in Table 2-29.
[d] COPCs based on screening of ROC-specific diet, as presented in Table 2-30.
[e] COPCs based on screening of ROC-specific diet, as presented in Table 2-33.
[f] COPCs based on screening of ROC-specific diet, as presented in Table 2-36.
[g] COPCs based on screening of ROC-specific diet, as presented in Table 2-37.

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
ROC – receptor of concern

2.7 Refined COPC screen

Per EPA guidance (1997a, 2001), in the screening step, COPCs are identified as those chemicals for which there is a potential for adverse effects; however, given the conservative nature of the screening step, a more thorough evaluation of site-specific risk is often warranted. This section presents the refined screening step, which was conducted following EPA guidance (EPA 2001). The refined COPC screen resulted in a more focused list of COPCs for evaluation in the baseline ERA.

Per EPA guidance, as part of the refined COPC screening process, "COPCs may be further refined to help streamline the overall ERA process by considering additional components early in the baseline ERA" (EPA 2001). These additional components include: consideration of background, consideration of frequency and magnitude of detection, and consideration of dietary uptake (such as nutritional requirements). In consultation with EPA, the refined screening step for the Harbor Oil baseline ERA takes into account one of these considerations: comparison of Study Area concentrations with background/reference areas[21] concentrations to eliminate COPCs from the Study Area that are equal to or less than those in background/reference areas (presented in Section 2.7.1). Section 2.7.2 presents a summary of the refined COPCs that were evaluated further in the baseline ERA.

2.7.1 Evaluation of Background

Study Area concentrations of the COPCs for each of the receptor groups identified in Section 2.6 were compared with background or reference area (urban areas within the vicinity of the Study Area) concentrations (see Attachment 4 for details regarding background and reference area concentrations). COPCs that had Study Area concentrations that were similar to or less than background or reference area concentrations were eliminated in the refined COPC screening step.

Tables 2-40 and 2-41 present the refined COPC screening results for aquatic benthic and terrestrial invertebrates, respectively. For aquatic benthic and terrestrial invertebrates, COPCs for which maximum Study Area concentrations were less than or equal to background or reference area concentrations were not retained for further analysis. Tables 2-42 through 2-47 present the refined COPC screening results for fish, bird, and mammal receptors. For fish, bird, and mammals, COPCs for which UCL Study Area concentrations were less than or equal to background or reference area concentrations were not retained for further analysis. The UCL was compared to background for these more mobile receptors because their exposure is integrated across the Study Area.

[21] The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA. Instead, concentrations from reference areas (urban areas in the vicinity of the Study Area) area presented for comparison with Study Area concentrations.

Table 2-40. Aquatic Benthic Invertebrate Refined COPC Screening Results for Surface Sediment and Surface Water

Aquatic Benthic Invertebrate COPC	Unit	Sediment or Water Concentration		Retained as a Refined COPC?[b]
		Study Area (maximum)	Background/ Reference Area[a]	
Sediment (dw)				
Metals				
Arsenic	mg/kg	7	7 – 7.9	no
Cadmium	mg/kg	2	0.5 – 1	**yes**
Copper	mg/kg	72	12	**yes**
Lead	mg/kg	56	2.0 – 17	**yes**
Mercury	mg/kg	0.2 J	0.07 – 2	no
Nickel	mg/kg	31	20	**yes**
Zinc	mg/kg	229	53	**yes**
PAHs				
Benzo(a)anthracene	µg/kg	74	72 – 87	no
Benzo(a)pyrene	µg/kg	83	90 – 100	no
Chrysene	µg/kg	110	103 – 129	no
Fluoranthene	µg/kg	190	132 – 144	**yes**
Phenanthrene	µg/kg	120	80 – 88	**yes**
Pyrene	µg/kg	180	196 – 196	no
PCBs				
Total PCBs	µg/kg	131	23 – 24	**yes**
Pesticides				
2,4′-DDD	µg/kg	61 JN	6.1 – 6.7	**yes**
4,4′-DDD	µg/kg	47	6.1 – 6.7	**yes**
4,4′-DDE	µg/kg	150	7 – 9.8	**yes**
Total DDTs	µg/kg	250	16 – 19	**yes**
Surface Water				
Barium	µg/L	31	na	no[c]
Copper	µg/L	4.0	9	no

a Details and sources of reference area (urban areas in the vicinity of the Study Area) concentrations are presented in Attachment 4.

b COPCs with maximum Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

c Background surface water concentrations are not available for barium; however, barium sediment concentrations in Force Lake (ranging from 128 to 220 mg/kg dw) were less than the background soil concentration (502 mg/kg dw) (no background sediment concentration was available; see Attachment 4). Therefore, barium was not retained as a COPC for surface water.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
J – estimated concentration
N – tentative identification
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

Bold identifies refined COPCs.

Table 2-41. Terrestrial Invertebrate Refined COPC Screening Results for Soil

Terrestrial Invertebrate COPC	Unit (dw)	Soil Concentration		Retained as a Refined COPC?[b]
		Study Area Wetland Soil (maximum)	Background/ Reference Area[a]	
Metals				
Aluminum	mg/kg	12,100	37,200	no
Barium	mg/kg	481	502	no
Chromium	mg/kg	149	42	**yes**
Copper	mg/kg	1,240 J	36	**yes**
Manganese	mg/kg	1,090	1,100	no
Mercury	mg/kg	0.4	0.07	**yes**
Zinc	mg/kg	748	86	**yes**
PAHs				
Total HPAHs	µg/kg	57,000	54 – 388	**yes**

[a] Details and sources of reference area (urban areas in the vicinity of the Study Area) concentrations are presented in Attachment 4.

[b] COPCs with maximum Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

COPC – contaminant of potential concern

dw – dry weight

HPAH – high-molecular-weight polycyclic aromatic hydrocarbon

J – estimated concentration

PAH – polycyclic aromatic hydrocarbon

Bold identifies refined COPCs.

Table 2-42. Pumpkinseed and Brown Bullhead Refined COPC Screening Results

Fish COPC	Unit	Sediment or Water Concentration		Retained as a Refined COPC?[b]
		Study Area (UCL)	Background/ Reference Area[a]	
Sediment (dw)				
Total PCBs	µg/kg	120	23 – 24	**yes**
Cadmium	mg/kg	2[c]	0.5 – 1	**yes**
Copper	mg/kg	72[d]	12	**yes**
Vanadium	mg/kg	67	67.3[e]	no
Surface Water				
Barium	µg/L	31[f]	na	no[g]
Copper	µg/L	4.0[f]	9	no

a Details and sources of reference area (urban areas within the vicinity of the Study Area) concentrations are presented in Attachment 4.

b COPCs with Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

c Value is maximum detected concentration; all detected values were equal, and thus there were too few unique values for use in ProUCL (Attachment 3).

d Value is maximum detected concentration; UCL concentration (78 mg/kg dw) is greater than maximum concentration (Attachment 3).

e No sediment background value is available (Attachment 4); background value is represented by a soil background concentration.

f Value is maximum detected concentration; there were too few unique values for use in ProUCL (Attachment 3).

g Background surface water concentrations are not available for barium; however, barium sediment concentrations in Force Lake (ranging from 128 to 220 mg/kg dw) were less than the background soil concentration (502 mg/kg dw) (no background sediment concentration is available; see Attachment 4). Therefore, barium was not retained as a COPC for surface water.

COPC – contaminant of potential concern
PCB – polychlorinated biphenyl
dw – dry weight
UCL – upper confidence limit on the mean

Bold identifies refined COPCs.

Table 2-43. Ruddy Duck Refined COPC Screening Results

Ruddy Duck COPC	Unit (dw)	Sediment Concentration		Retained as a Refined COPC?[b]
		Study Area (UCL)	Background/ Reference Area[a]	
Metals				
Mercury	mg/kg	0.20	0.07 – 0.2	**yes**[c]
Vanadium	mg/kg	67	67.3[d]	no
Pesticides				
Total DDTs	µg/kg	200	16 – 19	**yes**

[a] Details and sources of reference area (urban areas within the vicinity of the Study Area) concentrations are presented in Attachment 4.

[b] COPCs with Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

[c] Although Study Area concentrations were similar to background concentrations, mercury was retained because COPCs that are known to have a high potential to accumulate and persist in the food chain should not be screened out based on background in the refined screening process (EPA 2001).

[d] No sediment background value is available (Attachment 4); background value is represented by a soil background concentration.

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
UCL – upper confidence limit on the mean

Bold identifies refined COPCs.

Table 2-44. Great Blue Heron Refined COPC Screening Results

Great Blue Heron COPC	Unit (dw)	Sediment Concentration		Retained as a Refined COPC?[b]
		Study Area (UCL)	Background/ Reference Area[a]	
Metals				
Vanadium	mg/kg	67	67.3[c]	no
Pesticides				
Total DDTs	µg/kg	200	16 – 19	**yes**

[a] Details and sources of reference area (urban areas within the vicinity of the Study Area) concentrations are presented in Attachment 4.

[b] COPCs with Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

[c] No sediment background value is available (Attachment 4); background value is represented by a soil background concentration.

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
UCL – upper confidence limit on the mean

Bold identifies refined COPCs.

Table 2-45. Red-Tailed Hawk Refined COPC Screening Results

Red-Tailed Hawk COPC	Unit (dw)	Soil Concentration		Retained as a Refined COPC?[b]
		Study Area (UCL)	Background/ Reference Area[a]	
Metals				
Aluminum	mg/kg	12,000[c]	37,200	no
Pesticides				
Total DDTs	µg/kg	8,500	15 – 355	**yes**

[a] Details and sources of reference area (urban areas within the vicinity of the Study Area) concentrations are presented in Attachment 4.

[b] COPCs with Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

[c] Value is maximum detected concentration; there were too few unique values for use in ProUCL (Attachment 3).

COPC – contaminant of potential concern
dw – dry weight
DDT – dichlorodiphenyltrichloroethane
UCL – upper confidence limit on the mean

Bold identifies refined COPCs.

Table 2-46. Eastern Cottontail Refined COPC Screening Results

Eastern Cottontail COPC	Unit (dw)	Soil Concentration		Retained as a Refined COPC?[b]
		Study Area (UCL)	Background/ Reference Area[a]	
Metals				
Aluminum	mg/kg	12,000[c]	37,200	no
Cobalt	mg/kg	12	na	**yes**
Copper	mg/kg	150	36	**yes**
Mercury	mg/kg	0.16	0.07	**yes**
Selenium	mg/kg	1.5	2	no
Vanadium	mg/kg	74	67.3	**yes**
PAHs				
Total PAHs	µg/kg	8,300	68 – 427	**yes**

[a] Details and sources of reference area (urban areas within the vicinity of the Study Area) concentrations are presented in Attachment 4.

[b] COPCs with Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

[c] Value is maximum detected concentration; there were too few unique values for use in ProUCL (Attachment 3).

COPC – contaminant of potential concern
dw – dry weight
na – not available
PAH – polycyclic aromatic hydrocarbon
UCL – upper confidence limit on the mean

Bold identifies refined COPCs.

Table 2-47. Shrew Refined COPC Screening Results

Shrew COPC	Unit (dw)	Soil Concentration		Sediment Concentration		Retained as a Refined COPC?[b]
		Study Area (UCL)	Background/ Reference Area[a]	Study Area (UCL)	Background/ Reference Area[a]	
Metals						
Aluminum	mg/kg	12,000[c]	37,200	na	37,200[d]	no
Arsenic	mg/kg	9.3	7	6.4	7 – 7.9	**yes[e]**
Cadmium	mg/kg	1	1	2[f]	0.5 – 1	**yes[e]**
Cobalt	mg/kg	12	na	14	na	**yes**
Copper	mg/kg	150	36	72[g]	12	**yes**
Lead	mg/kg	78	17	40[h]	2.0 – 17	**yes**
Mercury	mg/kg	0.16	0.07	0.20	0.07 – 0.2	**yes**
Nickel	mg/kg	24	38	27	20	no[e]
Selenium	mg/kg	1.5	2	4.0 (nd)[i]	0.4 – 2[d]	no[j]
Vanadium	mg/kg	74	67.3	67	67.3[d]	no
Zinc	mg/kg	240	86	200	53	**yes**
PAHs						
Total PAHs	µg/kg	8,300	68 – 427	740	1,073 – 1,078	**yes[e]**
PCBs						
Total PCBs	µg/kg	680	23 – 24[k]	120	23 – 24	**yes**
Pesticides						
Total DDTs	µg/kg	8,500	15 – 355	200	16 – 19	**yes**

a Details and sources of reference area (urban areas within the vicinity of the Study Area) concentrations are presented in Attachment 4.

b COPCs with Study Area concentrations less than or equal to background or reference area concentrations were not retained as refined COPCs.

c Value is maximum detected concentration; there were too few unique values for use in ProUCL (Attachment 3).

d No sediment background value is available; sediment background value is for soil.

e In cases where Study Area sediment and soil concentrations were not below or similar to background/reference area sediment and soil concentrations, respectively, the determination of whether the COPC was retained as a refined COPC was made based on whether a weighted Study Area sediment/soil concentration (based on 70% soil and 30% sediment according to the dietary type of invertebrates assumed for shrew) was within or below the range of background or reference area concentrations.

f Value is maximum detected concentration; all detected values were equal, and thus there were too few unique values for use in ProUCL (Attachment 3).

g Value is maximum detected concentration; UCL concentration (78 mg/kg dw) is greater than maximum concentration (Attachment 3).

h Value is maximum detected concentration; UCL concentration (56 mg/kg dw) is greater than maximum concentration (Attachment 3).

i Value is maximum RL; selenium was not detected in any sediment samples collected from Force Lake (Attachment 3).

j Selenium was not retained as a COPC because Study Area soil UCL (1.5 mg/kg dw) is less than the background soil concentration (2 mg/kg dw). The maximum sediment Study Area selenium RL (4 mg/kg dw) was higher than the range of sediment background concentrations (0.4 to 2 mg/kg); however, selenium was never detected in sediment.

[k] No soil reference area value is available; soil reference area value is for sediment.

COPC – contaminant of potential concern
dw – dry weight
DDT – dichlorodiphenyltrichloroethane
na – not analyzed
nd – not detected
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
UCL – upper confidence limit on the mean

Bold identifies refined COPCs.

2.7.2 Summary of Refined COPCs

The following COPCs were not retained as COPCs based on the refined screen because Study Area concentrations were similar to or less than background/reference area concentrations:

- **Aquatic benthic invertebrates:** arsenic, mercury, benzo(a)anthracene, benzo(a)pyrene, chrysene, and pyrene (in sediment), and barium and copper (in water)
- **Terrestrial invertebrates:** aluminum, barium, and manganese
- **Pumpkinseed and brown bullhead:** vanadium (in sediment), and barium and copper (in water)
- **Ruddy duck and great blue heron:** vanadium
- **Red-tailed hawk:** aluminum
- **Eastern cottontail:** aluminum and selenium
- **Shrew:** aluminum, nickel, selenium, and vanadium

Table 2-48 presents a refined list of COPCs for aquatic benthic and terrestrial invertebrates, and Table 2-49 presents the refined list for fish and wildlife ROCs. These refined COPCs represent in a more focused list of COPCs for evaluation in the baseline ERA and are evaluated further in Sections 3.0, 4.0, and 5.0.

Table 2-48. Summary of Invertebrate Refined COPCs

Refined COPC	Aquatic Benthic Invertebrate[a]	Terrestrial Invertebrate[b]
Metals		
Cadmium	X	
Chromium		X
Copper	X	X
Lead	X	
Mercury		X
Nickel	X	
Zinc	X	X
PAHs		
Fluoranthene	X	
Phenanthrene	X	
Total HPAHs		X
PCBs		
Total PCBs	X	
Pesticides		
2,4′-DDD	X	
4,4′-DDD	X	
4,4′-DDE	X	
Total DDTs	X	

[a] Aquatic benthic invertebrate refined COPCs are based on a comparison of background and reference area (urban areas in the vicinity of the Study Area) concentrations with Study Area sediment and surface water concentrations, as presented in Table 2-40.

[b] Terrestrial invertebrate refined COPCs are based on a comparison of background and reference area (urban areas within the vicinity of the Study Area) concentrations with Study Area soil concentrations, as presented in Table 2-41.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

Table 2-49. Summary of Fish and Wildlife ROC-Refined COPC Pairs

Refined COPC	Aquatic ROCs				Terrestrial ROCs		
	Pumpkin-seed[a]	Brown Bullhead[a]	Ruddy Duck[b]	Great Blue Heron[c]	Red-Tailed Hawk[d]	Eastern Cotton-tail[e]	Shrew[f]
Metals							
Arsenic							X
Cadmium	X	X					X
Cobalt						X	X
Copper	X	X				X	X
Lead							X
Mercury			X			X	X
Vanadium						X	
Zinc							X
PAHs							
Total PAHs						X	X
PCBs							
Total PCBs	X	X					X
Pesticides							
Total DDTs			X	X	X		X

[a] Refined COPCs are based on a comparison of background and reference area (urban areas within the vicinity of the Study Area) concentrations with Study Area sediment and surface water concentrations, as presented in Table 2-42.

[b] Refined COPCs are based on a comparison of background and reference area (urban areas within the vicinity of the Study Area) concentrations with Study Area sediment concentrations, as presented in Table 2-43.

[c] Refined COPCs are based on a comparison of background and reference area (urban areas within the vicinity of the Study Area) concentrations with Study Area sediment concentrations, as presented in Table 2-44.

[d] Refined COPCs are based on a comparison of background and reference area (urban areas within the vicinity of the Study Area) concentrations with Study Area soil concentrations, as presented in Table 2-45.

[e] Refined COPCs are based on a comparison of background and reference area (urban areas within the vicinity of the Study Area) concentrations with Study Area soil concentrations, as presented in Table 2-46.

[f] Refined COPCs are based on a comparison of background and reference area (urban areas within the vicinity of the Study Area) concentrations with Study Area soil and sediment concentrations, as presented in Table 2-47.

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
ROC – receptor of concern

3.0 EXPOSURE ASSESSMENT

This section describes how EPCs and dietary doses were developed for each of the ecological ROCs and measurement endpoints evaluated. Exposure concentrations are integrated with the effects data (Section 4.0) in the risk characterization section (Section 5.0) to determine risks in the form of hazard quotients (HQs). Uncertainties are discussed in Section 5.0.

3.1 Invertebrates

The following subsection describes how the exposure of aquatic and terrestrial invertebrates was assessed. The exposure of aquatic invertebrates to refined COPCs was evaluated using sediment data (no refined COPCs were identified for surface water [see Table 2-40]), and the exposure of terrestrial invertebrates was assessed using wetland soil data.

3.1.1 Sediment

In Section 5.1.1, risk to aquatic benthic invertebrates is assessed based on a comparison of Force Lake surface sediment data to sediment thresholds. Sediment thresholds are presented in Section 4.1.1. Aquatic benthic invertebrates are generally relatively immobile, and thus their exposure to sediment was assessed on a sample-by-sample basis. A summary of concentrations for all sediment refined COPCs is presented in Table 3-1.

Table 3-1. Summary of COPC Concentrations in Force Lake Surface Sediment

Refined COPC[a]	Unit (dw)	Detection Frequency (%)	EPC (Range of Detected Concentrations)	
			Minimum	Maximum
Metals				
Cadmium	mg/kg	8/11 (73)	2	2
Copper	mg/kg	11/11 (100)	16.2	72
Lead	mg/kg	11/11 (100)	9	56
Nickel	mg/kg	11/11 (100)	11	31
Zinc	mg/kg	11/11 (100)	80	229
PAHs				
Fluoranthene	µg/kg	11/11 (100)	20	190
Phenanthrene	µg/kg	11/11 (100)	15	120

Table 3-1. Summary of COPC Concentrations in Force Lake Surface Sediment

Refined COPC[a]	Unit (dw)	Detection Frequency (%)	EPC (Range of Detected Concentrations)	
			Minimum	Maximum
PCBs				
Total PCBs	µg/kg	7/11 (64)	93	131
Pesticides				
2,4′-DDD	µg/kg	8/11 (73)	8.6 JN	61 JN
4,4′-DDD	µg/kg	11/11 (100)	11 J	47
4,4′-DDE	µg/kg	11/11 (100)	9.1	150
Total DDTs	µg/kg	11/11 (100)	22 J	250

[a] Aquatic benthic invertebrate refined COPCs in sediment were determined in Table 2-40.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
J – estimated concentration
N – tentative identification
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

3.1.2 Wetland Soil

Risk to terrestrial invertebrates was assessed based on a comparison of wetland surface soil data to soil thresholds (Section 5.1.2). Terrestrial invertebrates are assumed to be relatively immobile, and thus their exposure to soil was assessed on a sample-by-sample basis. Soil thresholds are presented in Section 4.1.2. A summary of wetland soil data for the refined COPCs is presented in Table 3-2.

Table 3-2. Summary of Wetland Soil COPC Concentrations

Refined COPC[a]	Unit (dw)	Detection Frequency (%)	EPC (Range of Detected Concentration)	
			Minimum	Maximum
Metals				
Chromium	mg/kg	71/71 (100)	6.6	149
Copper	mg/kg	71/71 (100)	10.3	1,240 J
Mercury	mg/kg	64/71 (90)	0.04 J	0.4
Zinc	mg/kg	71/71 (100)	37	748
PAHs				
Total HPAHs	µg/kg	70/71 (99)	101 J	57,000

[a] Terrestrial invertebrate refined COPCs in soil were determined in Table 2-41.

COPC – contaminant of potential concern
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
J – estimated concentration
PAH – polycyclic aromatic hydrocarbon

3.2 Fish

The following subsection describes how EPCs were developed for assessing risks to fish.

3.2.1 Tissue-Residue EPCs

Risks to fish from bioaccumulative COPCs were assessed using a tissue-residue approach. Only one tissue refined COPC, total PCBs, was identified for the fish ROCs. Total PCB concentrations in brown bullhead and pumpkinseed were estimated using a sediment concentration, a BSAF, and ROC-specific lipid assumptions. Details on how BSAFs and lipid assumptions were selected are presented in Attachment 2. The sediment concentration used to estimate the tissue concentration was represented by the UCL concentration in sediment, as calculated using ProUCL 4.00.04 (EPA 2009c), which includes provisions for handling non-detected values (EPA 2009b). Summary statistics for all tissue EPCs are presented in Attachment 3. Data tables, including ProUCL 4.00.04 input and output data tables, are presented as an electronic attachment to Attachment 3A.

Table 3-3 presents the estimated total PCB concentrations in brown bullhead and pumpkinseed tissue based on the equation presented in Attachment 2 and the assumptions used to derive the EPC for each ROC.

Table 3-3. Fish Tissue Total PCBs EPCs

ROC	Sediment UCL	BSAF	BSAF Unit	Lipid (fraction)	Tissue EPC (ww)[a]
Brown bullhead	1.4 mg/kg OC	6.45	tiss lipid/sed OC	0.026	230 µg/kg
Pumpkinseed	1.4 mg/kg OC	6.45	tiss lipid/sed OC	0.031	280 µg/kg

[a] Tissue EPC (ww) = (BSAF x UCL_{sed}) x F_L, where F_L = fraction lipid.

BSAF – biota-sediment accumulation factor
EPC – exposure point concentration
OC – organic carbon
PCB – polychlorinated biphenyl
ROC – receptor of concern
UCL – upper confidence limit on the mean
ww – wet weight

3.2.2 Dietary Doses

Risks to fish from refined COPCs that are either metabolized (i.e., PAHs) or regulated (i.e., metals) were also assessed using a dietary-dose approach. Equation 3-1 presents the method used to calculate the dietary dose for fish ROCs (i.e., brown bullhead and pumpkinseed) based on the ingestion of biota prey and the incidental ingestion of sediment.

$$Dose_{diet} = \frac{(FIR \times EPC_{prey}) + (SIR \times EPC_{sed})}{BW} \times SUF \qquad \textbf{Equation 3-1}$$

Where:

$Dose_{diet}$	mg/kg bw/ day	estimated exposure dose
FIR	kg ww food/day	species-specific food ingestion rate
EPC_{prey}	mg /kg ww	exposure point concentration in prey tissue
SIR	kg dw food/day	species-specific incidental sediment ingestion rate
EPC_{sed}	mg /kg dw	exposure point concentration in sediment
BW	kg ww	species-specific body weight
SUF	fraction	site use factor

The diet for each ROC was estimated based on available literature, as discussed in detail in Section 3.2.2.1. The fraction of each prey item consumed by a ROC was multiplied by the concentration in that prey item according to Equation 3-2.

$$EPC_{prey} = (EPC_1 \times F_1) + (EPC_2 \times F_2)$$ **Equation 3-2**

Where:

EPC_{prey}	mg /kg ww	exposure point concentration in prey tissue (total diet)
$EPC_{1,2}$	mg /kg ww	exposure point concentration in each individual prey tissue
$F_{1,2}$	fraction	fraction consumed of each individual prey species

If sufficient data (i.e., six or more detected concentrations) were available, EPC_{sed} was represented by a UCL concentration calculated using ProUCL 4.00.04 (EPA 2009c), which includes provisions for handling non-detected values (EPA 2009b). The UCL recommended by ProUCL was used as the EPC_{sed} for the risk assessment unless the UCL was greater than the maximum detected concentration, in which case the maximum concentration was used as the EPC_{sed}. In some cases, insufficient data were available to calculate a UCL using ProUCL 4.00.04, and the EPC_{sed} was set equal to one-half of the maximum RL (if no detected results were available) or set equal to the maximum detect or one-half the maximum RL, whichever was greater.

Prey tissue concentrations (EPC_{prey}) were then estimated from the EPC_{sed}, a BSAF, and ROC-specific lipid assumptions. Details on how BSAFs and lipid assumptions were selected are presented in Attachment 2. Summary statistics for all sediment and prey tissue EPCs used in the dietary risk assessment for fish are presented in Attachment 3. Data tables, including ProUCL 4.00.04 input and output data tables, are presented as an electronic attachment to Attachment 3A.

3.2.2.1 Exposure Assumptions

In order to assess risks to fish based on a dietary pathway, it was necessary to estimate fish body weights, food ingestion rates, sediment ingestion rates, and dietary prey fractions.

Body weights were estimated based on available literature. No food or sediment ingestion rates were available; thus, Equations 3-3 and 3-4 (Arnot and Gobas 2004) were used to estimate these rates:

$$FIR = (0.022 \times BW^{0.85}) \times \exp^{(0.06 \times T)}$$ **Equation 3-3**

Where:

FIR	mg ww/kg/day	daily food ingestion rate
BW	kg	species-specific body weight
exp	unitless	constant (2.71829)
T	°C	average temperature

$$SIR = (FIR \times F_{soilds}) \times F_{sed}$$ **Equation 3-4**

Where:

SIR	mg dw/kg/day	daily sediment ingestion rate
FIR	mg ww/kg/day	daily food ingestion rate
F_{solids}	fraction	fraction of food that is dry weight (F_{solids} = 1 – $F_{moisture}$)
F_{sed}	fraction	fraction of diet that is sediment
exp	unitless	constant (2.71829)
T	°C	average lake temperature

The selected fish exposure parameters are presented in Table 3-4.

Table 3-4. Summary of Exposure Parameters for Fish ROCs

Parameter	Unit	Value	Reference and Rationale
Pumpkinseed			
Body weight	kg	0.015	Average body weight of pumpkinseed collected during April 2009 fish survey (Windward 2009b)
FIR	kg ww/day	0.0016	Based on Equation 3-3, assuming a temperature of 16 °C.[a]
SIR	kg dw/day	0.0000034	Calculated using Equation 3-4, assuming a conservative sediment ingestion rate of 1% of the FIR based on water surface or water column feeding habits (Mieiro et al. 2001) and a moisture content of 79%.[b]
SUF	unitless	1.0	Assumed that pumpkinseed forage throughout Force Lake and are limited to this exposure area.
Brown Bullhead			
Body weight	kg	0.40	Based on reported weights from several studies (EPA 2002b).
FIR	kg ww/day	0.026	Based on Equation 3-3, assuming a temperature of 16°C.[a]
SIR	kg dw/day	0.00055	Calculated using Equation 3-4, assuming a moderate sediment ingestion of 10% of a FIR based on bottom-feeding habits (EPA 2002b) and a moisture content of 79%.[b]
SUF	unitless	1.0	Assumed that brown bullhead forage throughout Force Lake and are limited to this exposure area.

[a] Water temperatures in shallow lakes such as Force Lake are likely to vary greatly with seasonal temperature changes. The lake temperature was measured at 11°C during

the April 2008 sampling event. A temperature of 16°C was used for this assessment to be reflective of annual mean temperatures, including higher summer temperatures.

[b] The FIR was converted to dw to calculate the SIR assuming 79% moisture based on average aquatic invertebrate moisture (EPA 1993b).

C – centigrade
dw – dry weight
EPA – US Environmental Protection Agency
FIR – food ingestion rate
ROC – receptor of concern
SIR – sediment ingestion rate
SUF – site use factor
ww – wet weight

Dietary prey portions were determined based on the literature as discussed below. Table 3-5 presents a summary of the prey fractions that were used to estimate dietary doses for fish ROCs.

Table 3-5. Prey Portions Selected for Fish ROCs

ROC	Benthic Invertebrates	Fish
Pumpkinseed	1.0	0
Brown bullhead	0.9	0.1

ROC – receptor of concern

Pumpkinseed: Pumpkinseed are reported to feed primarily on worms, crustaceans, small mollusks, and aquatic insects (FishBase 2007; Wydoski and Whitney 2003). These fish forage both in the water column and at the sediment surface. For this risk assessment, pumpkinseed were assumed to consume 100% aquatic invertebrate tissue. The calculated pumpkinseed prey concentrations (based on 100% ingestion of benthic invertebrates) are likely overestimated because this species generally feeds on both water-column and benthic invertebrates. This conservative approach was developed based on the availability of bioaccumulation data; this assumption was evaluated in the uncertainty analysis (Section 5.2.1.2).

Brown Bullhead: Adult brown bullhead are opportunistic bottom-feeders that feed predominantly on aquatic insects (e.g., midges), detritus, and plant material (FishBase 2007; EPA 2002b). Other prey items may include small fish, mollusks, leeches, crayfish, plankton, worms, and algae. Juvenile brown bullhead feed predominantly on aquatic larvae and small insects. Although a significant portion of the brown bullhead diet is likely plant material, information regarding the accumulation of chemicals in aquatic plants is not widely available. Therefore, the brown bullhead diet for this risk assessment was estimated based on 90% benthic invertebrates and 10% fish.

3.2.2.2 Calculated Dietary Doses

Estimated dietary dose concentrations for all fish diet refined COPCs are presented in Tables 3-6 and 3-7 for pumpkinseed and brown bullhead, respectively.

Table 3-6. Estimated Dietary Doses for Pumpkinseed

Refined COPC	Aquatic Invertebrate BSAF		EPC_{sed}		$EPC_{aquat\ invert}$		$Dose_{diet}$	
	Value	Unit	Value[a]	Unit	Value[b]	Unit	Value[d]	Unit
Cadmium	3.438	tiss dw/sed dw	2	mg/kg dw	1.4	mg/kg ww	0.15	mg/kg bw/day
Copper	2.14	tiss dw/sed dw	72[c]	mg/kg dw	32	mg/kg ww	3.5	mg/kg bw/day

a EPC_{sed} was based on UCL concentration when the dataset had six or more detects except where noted. See Attachment 3 for summary statistics on EPCs.

b $EPC_{aquatic\ invert}$ was estimated from EPC_{sed} and aquatic benthic invertebrate BSAF and converted to ww assuming a moisture content of 79%, where $EPC_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

c EPC_{sed} is based on the maximum detected concentration because the UCL concentration was greater than the maximum concentration (see Attachment 3).

d $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-4, and assumption that diet is comprised of 100% aquatic invertebrates.

BSAF – biota sediment accumulation factor
bw – body weight
COPC – contaminant of potential concern
dw – dry weight
EPC – exposure point concentration
UCL – upper confidence limit on the mean
ww – wet weight

Table 3-7. Estimated Dietary Doses for Brown Bullhead

Refined COPC	Prey BSAF			EPC_{sed}		C_{fish}		$C_{aquat\ invert}$		$Dose_{diet}$	
	Fish Value	Invertebrate Value	Unit	Value[a]	Unit	Value[b]	Unit	Value[c]	Unit	Value[e]	Unit
Cadmium	0.785	3.438	tiss dw/sed dw	2	mg/kg dw	0.44	mg/kg ww	1.4	mg/kg ww	0.089	mg/kg bw/day
Copper	1	2.14	tiss dw/sed dw	72[d]	mg/kg dw	20	mg/kg ww	32	mg/kg ww	2.1	mg/kg bw/day

a EPC_{sed} was based on UCL concentration when the dataset had six or more detects except where noted. See Attachment 3 for summary statistics on EPCs.

b EPC_{fish} was estimated from EPC_{sed} and fish BSAF and converted to ww assuming a moisture content of 72%, where EPC_{fish} (ww) = (BSAF x EPC_{sed}) x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

c $EPC_{aquatic\ invert}$ was estimated from EPC_{sed} and aquatic benthic invertebrate BSAF and converted to ww assuming a moisture content of 79%, where $EPC_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

d EPC_{sed} is based on the maximum detected concentration because the UCL concentration was greater than the maximum concentration (see Attachment 3).

e $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-4, and assumption that diet is composed of 10% fish and 90% aquatic invertebrates.

BSAF – biota sediment accumulation factor
bw – body weight
COPC – contaminant of potential concern
dw – dry weight
EPC – exposure point concentration
UCL – upper confidence limit on the mean
ww – wet weight

3.3 Birds and Mammals

Risks to birds and mammals from all refined COPCs were assessed using a dietary-dose approach. The same equation used to calculate the dietary dose for fish (Equation 3-1) was used to calculate the dietary dose for aquatic bird ROCs (i.e., ruddy duck and great blue heron). Equation 3-5 presents the method used to calculate the dietary dose for terrestrial ROCs (i.e., Eastern cottontail, shrew, and red-tailed hawk) based on the ingestion of biota prey and the incidental ingestion of soil.

$$Dose_{diet} = \frac{(FIR \times EPC_{prey}) + (SIR \times EPC_{sed})}{BW} \times SUF \qquad \textbf{Equation 3-5}$$

Where:

$Dose_{diet}$	mg/kg bw/day	estimated exposure dose
FIR	kg ww food/day	species-specific food ingestion rate
EPC_{prey}	mg ww/kg	exposure point concentration in prey tissue
SIR	kg dw food/day	species-specific incidental or soil ingestion rate
EPC_{soil}	mg dw/kg	exposure point concentration in soil
BW	kg ww	species-specific body weight
SUF	fraction	site use factor

The diet for each ROC was estimated based on available literature. The fraction of each prey item consumed by a ROC was multiplied by the concentration in that prey item, as shown in Equation 3-2.

If sufficient data (i.e., six or more detected concentrations) were available, the EPC_{sed} (for aquatic ROCs) or the EPC_{soil} (for terrestrial ROCs) was represented by a UCL concentration calculated using ProUCL 4.00.04 (EPA 2009c), which includes provisions for handling non-detected values (EPA 2009b). The UCL recommended by ProUCL was used as the EPC_{sed} or EPC_{soil} for the risk assessment unless the UCL was greater than the maximum detected concentration, in which case the maximum concentration was used as the EPC_{sed} or EPC_{soil}. In some cases, insufficient data were available to calculate a UCL using ProUCL, and the EPC_{sed} or EPC_{soil} was set equal to the higher of either the maximum detect or one-half of the maximum RL.

Prey tissue concentrations (EPC_{prey}) were then estimated from the EPC_{sed} or the EPC_{soil}, a BSAF or a BAF, and prey-specific lipid and percent moisture assumptions. Details on how BSAFs, BAFs, and assumptions were selected are presented in Attachment 2. Summary statistics for all sediment, soil, and prey tissue EPCs used in the dietary risk assessment for birds and mammals are presented in Attachment 3. Data tables, including ProUCL 4.00.04 input and output data tables, are presented as an electronic attachment to Attachment 3A.

3.3.1 Exposure Assumptions

In order to assess risks to bird and mammal ROCs using a dietary-dose approach, it was necessary to estimate body weights, food ingestion rates, sediment ingestion rates, and dietary preferences. Body weights and ingestion rates were estimated based on the available literature, and the selected values are presented in Table 3-8.

Table 3-8. Summary of Body Weights and Ingestion Rates for Bird and Mammal ROCs

Parameter	Unit	Value	Reference and Rationale
Ruddy Duck			
Body weight	kg	0.54	Reported average body weights from various studies ranged from 0.491 to 0.598 kg during the fall and winter (Brua 2002). Female body weights were reported as high as 0.817 kg during egg-laying. The average fall/winter body weight was used as a conservative assumption.
FIR	kg ww/day	0.19[b]	No species-specific information was available; therefore, the general bird allometric equation for estimating the FIR in kg dw/day was used (FIR = 0.0582 x $BW^{0.651}$) (Nagy 1987, as cited in EPA 1993).
SIR	kg dw/day	0.0039	Ruddy ducks generally feed by diving and inserting their bills into the sediment (Brua 2002). Based on these feeding habits, a moderate level of incidental sediment ingestion may occur. For this risk assessment, a SIR of 10% of the FIR on a dry-weight basis was assumed.
SUF	unitless	1.0	Force Lake represents the only breeding and nesting area within the Portland urban growth boundary (Fishman 1989), and thus ruddy ducks are present in the lake while breeding. Because ruddy ducks are a migratory species and may not be present at the Study Area year-round, an SUF of 0.5 was also evaluated in the uncertainty analysis of the risk characterization (Section 5.3.1.2).
Great Blue Heron			
Body weight	kg	2.3	Reported adult body weights ranged from 2.2 to 2.6 kg in two studies. The yearling body weight reported in a central Oregon study (2.3 kg) was within this range (Bayer 1981),[a] and was used in the risk assessment.
FIR	kg ww/day	0.41	The calculated FIR assumed an ingestion rate based the consumption of 18% of the heron body weight on a wet-weight basis (Kushlan 1978).[a]
SIR	kg dw/day	0.0023[c]	Sample and Suter (1994) reported that sediment ingestion is likely negligible. However, based on heron feeding habits, a moderate level of incidental sediment ingestion could occur. Thus, a SIR of 2% of the FIR on a dry-weight basis was assumed.
SUF	unitless	1.0	A great blue heron rookery is located 0.8 km from the Study Area, and heron foraging grounds are generally close to breeding colonies (3 to 8 km) (EPA 1993b). Feeding territories of great blue heron range from 0.6 to 8.4 hectares (EPA 1993b), and the estimated area of Force Lake is 4 to 5 hectares. Because great blue heron may also forage in nearby water bodies (e.g., Columbia Slough) and thus may not forage exclusively from Force Lake, an SUF of 0.5 was also evaluated in the uncertainty analysis of the risk characterization (Section 5.3.2.2).
Red-Tailed Hawk			
Body weight	kg	1.06	Average adult body weight from study in southwest Idaho (Steenhof 1983).[a]
FIR	kg ww/day	0.10	The calculated FIR is based on a percentage of food consumed relative to body weight. Seasonal FIRs ranged from 8.6 to 11% of the body weight on a wet-weight basis in a Michigan study (Craighead and Craighead 1956).[a] The average percentage of 9.9% was used to estimate the FIR.
SIR	kg dw/day	0.00034[d]	Based on hawk feeding habits, only a small amount of incidental sediment ingestion is likely; Sample and Suter (1994) reported that it is likely negligible. A conservative SIR of 1% of the FIR on a dry-weight basis was assumed.

Table 3-8. Summary of Body Weights and Ingestion Rates for Bird and Mammal ROCs

Parameter	Unit	Value	Reference and Rationale
SUF	unitless	0.1	Red-tailed hawk are likely to forage within the wetland soils as well as other terrestrial areas. Red-tailed hawk home ranges can be quite large, ranging up to 1,500 hectares (EPA 1993b). The wetland area sampled covers an area of approximately 1.9 hectares, so it was conservatively estimated that the wetland area sampled represents 10% of the red-tailed hawk foraging area. An SUF of 1.0 was also evaluated in the uncertainty analysis of the risk characterization (Section 5.3.3.2).
Eastern Cottontail			
Body weight	kg	1.2	Low end of average body weights reported in studies cited by EPA (1993b). Also reported as the mean male and female body weight in a study by Chapman et al. (1980).[f]
FIR	kg ww/day	0.237	As reported by Dalke and Sime (1988).[f]
SIR	kg dw/day	0.0031[g]	According to Sample and Suter (1994), sediment ingestion was assumed to be comparable to the black-tailed jackrabbit. Arthur and Gates (1988)[f] reported a SIR of 6.3% for this species.
SUF	unitless	1.0	A small home range was estimated to encompass the entire wetland area (covering an area of approximately 1.9 hectares); home ranges are generally between 1 and 3 hectares (2.5 to 7 acres) (EPA 1993b; Sample and Suter 1994).
Shrew			
Body weight	kg	0.015	Average body weight as presented by Schlesinger and Potter (1974).[a]
FIR	kg ww/day	0.0084	The calculated FIR assumed an ingestion rate based on percent ingestion relative to body weight. The average of 56% was used for shrew (Barrett and Stueck 1976).[a]
SIR	kg dw/day	0.00032[e]	A SIR of 13% of the FIR on a dry-weight basis was reported by Talmage and Walton (1993).[f]
SUF	unitless	1.0	A small home range was estimated to encompass the entire wetland area sampled (covering an area of approximately 1.9 hectares); the summer home range of a short-tailed shrew is < 0.1 to 1.8 hectares (0.2 to 4.4 acres), with an average year-round home range of 0.39 hectare (approximately 1 acre) (EPA 1993b).

[a] As cited in EPA's *Wildlife Exposure Factors Handbook* (1993b).

[b] The FIR was converted to ww assuming 79% moisture based on average aquatic invertebrate moisture (EPA 1993b).

[c] The FIR was converted to dw to calculate the SIR assuming 72% moisture based on average fish moisture (EPA 1993b).

[d] The FIR was converted to dw to calculate the SIR assuming 68% moisture based on average small mammal moisture (EPA 1993b).

[e] The FIR was converted to dw to calculate the SIR assuming an average terrestrial invertebrate moisture of 71% (EPA 1993b).

[f] As cited in Sample and Suter (1994).

[g] The FIR was converted to dw to calculate the SIR assuming an average grass shoot moisture content of 79% (EPA 1993b).

dw – dry weight
EPA – US Environmental Protection Agency
FIR – food ingestion rate
ROC – receptor of concern
SIR – sediment ingestion rate
SUF – site use factor

Dietary prey portions were determined based on the literature as discussed below. Table 3-9 presents a summary of the prey fractions that were used to estimate dietary doses for fish ROCs.

Table 3-9. Prey Portions Selected for Bird and Mammal ROCs

	Aquatic Prey		Terrestrial Prey			
ROC	**Inverte-brates**	**Fish**	**Plants**	**Inverte-brates**	**Earth-worms**	**Small Mammals**
Ruddy duck	1.0	0	na	na	na	na
Great blue heron	0.05	0.95	na	na	na	na
Red-tailed hawk	na	na	0	0	0	1.0
Eastern cottontail	na	na	1.0	0	0	0
Shrew	0.30	0	0	0.40	0.30	0

na – not applicable

ROC – receptor of concern

Ruddy duck: Various studies have examined the diet of the ruddy duck, with most studies reporting that animal matter made up more than 90% of the diet (Brua 2002). However, the consumption of animal matter was much lower in some studies of feeding habits at wintering grounds (Brua 2002; Marshall et al. 2003). Another source stated that ruddy duck consume approximately 75% plant material, although the observation season was not stated (Csuti et al. 2001). The most commonly eaten invertebrates were midge larvae, leeches, amphipods, and gastropods (Brua 2002). Based on the diet information, and because aquatic plant accumulation information is not widely available, ruddy duck were assumed to consume 100% aquatic invertebrate tissue.

Great blue heron: The diet of great blue heron consists primarily of small fish but may also include amphibians, reptiles, insects, birds, and mammals (EPA 1993b). The percentage of fish in heron diets ranged from 94 to 100%, and the species consumed varied by location. Studies of these birds have reported the consumption of fish up to 25 cm in length (Kirkpatrick 1940).[22] For this risk assessment, great blue heron were assumed to consume 95% fish and 5% aquatic invertebrates.

Red-tailed hawk: The diet of the red-tailed hawk can vary by location and season because hawk are known to prey opportunistically on available prey items. In general, the diet of red-tailed hawk consists primarily of small mammals, including squirrels, mice, gophers, rabbits, and other similar species (EPA 1993b). In addition, red-tailed hawk occasionally prey on small birds, reptiles, and insects. A study conducted in pastures and wheat fields in Oregon reported the following dietary proportions: 78.5% small mammals, 8.5% birds, and 13.1% snakes (Janes 1984).[23] Based on the diet information and the availability of BAFs to model prey data, a diet of 100% small mammals was assumed.

[22] As cited in EPA's *Wildlife Exposure Factors Handbook* (1993b).
[23] As cited in EPA's *Wildlife Exposure Factors Handbook* (1993b).

Short-tailed shrew: Short-tailed shrew are carnivores that feed almost entirely on invertebrates (e.g., insects, slugs, snails, and worms), although they may also eat plant material (EPA 1993b). Several studies have analyzed the stomach contents of shrew and have found that insects (terrestrial and aquatic), slugs, snails, and earthworms are the primary components of the shrew diet. Earthworms can constitute approximately 30% of the shrew diet (Csuti et al. 2001; Sample and Suter 1994). For this risk assessment, shrew were assumed to consume 30% earthworms, 40% other terrestrial invertebrates, and 30% aquatic invertebrates.

Eastern cottontail: Eastern cottontail are known to consume an exclusively herbivorous diet (EPA 1993b; Sample and Suter 1994). Feeding observation and stomach content studies have found that Eastern cottontail generally eat herbaceous plants (e.g., grasses and clover) during the spring and summer and bark, twigs, and other dried plant materials during the fall and winter. For this risk assessment, Eastern cottontail were evaluated based on the consumption of 100% terrestrial plants.

3.3.2 Calculated Dietary Doses

Estimated dietary doses for all bird and mammal diet refined COPCs are presented in Tables 3-10 through 3-14.

Table 3-10. Estimated Dietary Doses for Ruddy Duck

Refined COPC	Aquatic Invertebrate BSAF		EPC_{sed}		$EPC_{aquat\ invert}$		$Dose_{diet}$	
	Value	Unit	Value[a]	Unit	Value[b]	Unit	Value[c]	Unit
Mercury	1.20	tiss dw/sed dw	0.20	mg/kg dw	0.051	mg/kg ww	0.019	mg/kg bw/day
Total DDTs	5.21	tiss lipid/sed OC	2.7	mg/kg OC	170	µg/kg ww	58	µg/kg bw/day

[a] EPC_{sed} was based on UCL concentration when the dataset had six or more detects. See Attachment 3 for summary statistics on EPCs.

[b] $EPC_{aquatic\ invert}$ was estimated from EPC_{sed} (as a dw concentration or an OC-normalized concentration) and aquatic benthic invertebrate BSAF. When the sediment EPC was dw, the following equation was used: $EPC_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x (1 – F_M). When the sediment EPC was OC-normalized, the following equation was used: where F_M = fraction moisture; where EPC_{sed} (OC), $EPC_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x F_L, where F_L = fraction lipid. $EPC_{aquatic\ invert}$ was converted to ww assuming a moisture content of 79% or a lipid content of 1.2%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[c] $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-8, and assumption that diet is composed of 100% aquatic invertebrates.

BSAF – biota-sediment accumulation factor
bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
OC – organic carbon
UCL – upper confidence limit on the mean
ww – wet weight

Table 3-11. Estimated Dietary Doses for Great Blue Heron

Refined COPC	Prey BSAF			EPC_{sed}		EPC_{fish}		$EPC_{aquat\ invert}$		$Dose_{diet}$	
	Fish Value	Aquatic Invertebrate Value	Unit	Value[a]	Unit	Value[b]	Unit	Value[c]	Unit	Value[d]	Unit
Total DDTs	3.0	5.21	tiss lipid/sed OC	2.7	mg/kg dw	300	mg/kg ww	170	mg/kg ww	53	µg/kg bw/day

[a] EPC_{sed} was based on UCL concentration when the dataset had six or more detects. See Attachment 3 for summary statistics on EPCs.

[b] EPC_{fish} was estimated from EPC_{sed} and fish BSAF and converted to ww assuming a moisture content of 72%. When the sediment EPC was dw, the following equation was used: EPC_{fish} (ww) = (BSAF x EPC_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment EPC was OC-normalized, the following equation was used: EPC_{fish} (ww) = (BSAF x EPC_{sed}) x F_L, where F_L = fraction lipid. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[c] $EPC_{aquatic\ invert}$ was estimated from EPC_{sed} and aquatic benthic invertebrate BSAF and converted to ww assuming a moisture content of 79%. When the sediment EPC was dw, the following equation was used: $EPC_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment EPC was OC-normalized, the following equation was used: $EPC_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x F_L, where F_L = fraction lipid. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

[d] $Dose_{diet}$ was calculated using Equation 3-1, exposure parameters presented in Table 3-8, and assumption that diet is composed of 95% fish and 5% aquatic invertebrates.

BSAF – biota-sediment accumulation factor
bw – body weight
COPC – contaminant of potential concern
dw – dry weight
EPC – exposure point concentration
UCL – upper confidence limit on the mean
ww – wet weight

Table 3-12. Estimated Dietary Doses for Red-Tailed Hawk

Refined COPC	Mammal BAF		EPC_{soil}		EPC_{mammal}		$Dose_{diet}$	
	Value	Unit	Value[a]	Unit	Value	Unit	Value[b]	Unit
Total DDTs	EPC_{mammal} = ([EPC_{plant} x 0.75]+[EPC_{invert} x 0.25]) x 4.83	tiss dw/sed dw	8,500	µg/kg dw	37,000[c]	µg/kg ww	370	µg/kg bw/day

a EPC_{soil} was based on UCL concentration when the dataset had six or more detects. See Attachment 3 for summary statistics on EPCs.

b $Dose_{diet}$ was calculated using Equation 3-5, exposure parameters presented in Table 3-8, and assumption that diet is composed of 100% terrestrial small mammals.

c EPC_{mammal} was calculated using BAF regression, where EPC_{plant} = 73 µg/kg dw and EPC_{invert} = 95,200 µg/kg dw. EPC_{mammal} was converted to ww assuming a moisture content of 68% and where EPC_{mammal} (ww) = EPC_{mammal} (dw) x (1 – F_M), where F_M = fraction moisture.

BAF – bioaccumulation factor
bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
OC – organic carbon
UCL – upper confidence limit on the mean
ww – wet weight

Table 3-13. Estimated Dietary Doses for Eastern Cottontail

Refined COPC	Plant BAF		EPC_{soil}		EPC_{plant}		$Dose_{diet}$	
	Value	Unit	Value[a]	Unit	Value[b]	Unit	Value[c]	Unit
Cobalt	0.0075	tiss dw/sed dw	12	mg/kg dw	0.019	mg/kg ww	0.035	mg/kg bw/day
Copper	0.341	tiss dw/sed dw	150	mg/kg dw	11	mg/kg ww	2.6	mg/kg bw/day
Mercury	1.481	tiss dw/sed dw	0.16	mg/kg dw	0.050	mg/kg ww	0.010	mg/kg bw/day
Vanadium	0.00485	tiss dw/sed dw	74	mg/kg dw	0.075	mg/kg ww	0.21	mg/kg bw/day
Total PAHs	6.15	tiss dw/sed dw	8,300	µg/kg dw	11,000	µg/kg ww	2,200	µg/kg bw/day

[a] EPC_{soil} was based on UCL concentration when the dataset had six or more detects. See Attachment 3 for summary statistics on EPCs.

[b] EPC_{plant} was estimated from EPC_{soil} and plant BAF and converted to ww assuming a moisture content of 79%, and where EPC_{plant} (ww) = [BAF(dw/dw) x EPC_{soil}] x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BAFs and assumptions used to estimate prey tissue concentrations.

[c] $Dose_{diet}$ was calculated using Equation 3-5, exposure parameters presented in Table 3-8, and assumption that diet is composed of 100% terrestrial plants.

BAF – bioaccumulation factor
bw – body weight
COPC – contaminant of potential concern
dw – dry weight
EPC – exposure point concentration
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
UCL – upper confidence limit on the mean
ww – wet weight

Table 3-14. Estimated Dietary Doses for Shrew

Refined COPC	Invert BAF		Aquatic Invert BSAF		EPC_{soil}		EPC_{sed}		EPC_{invert}		$EPC_{aquat\ invert}$		$Dose_{diet}$	
	Value	Unit	Value	Unit	Value[a]	Unit (dw)	Value[b]	Unit	Value[c]	Unit (ww)	Value[d]	Unit (ww)	Value[e]	Unit
Arsenic	0.258	tiss dw/sed dw	0.24	tiss dw/sed dw	9.3	mg/kg	6.4	mg/kg dw	0.70	mg/kg	0.32	mg/kg	0.52	mg/kg bw/day
Cadmium	17.105	tiss dw/sed dw	3.438	tiss dw/sed dw	1	mg/kg	2.0	mg/kg dw	5.0	mg/kg	1.4	mg/kg	2.2	mg/kg bw/day
Cobalt	0.122	tiss dw/sed dw	1	tiss dw/sed dw	12	mg/kg	14	mg/kg dw	0.42	mg/kg	2.9	mg/kg	0.91	mg/kg bw/day
Copper	0.754	tiss dw/sed dw	2.14	tiss dw/sed dw	150	mg/kg	72[g]	mg/kg dw	33	mg/kg	32	mg/kg	21	mg/kg bw/day
Lead	3.342	tiss dw/sed dw	0.331	tiss dw/sed dw	78	mg/kg	56[g]	mg/kg dw	76	mg/kg	3.9	mg/kg	32	mg/kg bw/day
Mercury	5.231	tiss dw/sed dw	1.204	tiss dw/sed dw	0.16	mg/kg	0.20	mg/kg dw	0.24	mg/kg	0.051	mg/kg	0.11	mg/kg bw/day
Zinc	5.766	tiss dw/sed dw	3.473	tiss dw/sed dw	240	mg/kg	200	mg/kg dw	400	mg/kg	150	mg/kg	190	mg/kg bw/day
Total PAHs	2.87	tiss dw/sed dw	0.923	tiss lipid/sed OC	8,300	µg/kg	12	mg/kg OC	6,900	µg/kg	130	µg/kg	2,900	µg/kg bw/day
Total PCBs	8.91	tiss dw/sed dw	2.57	tiss lipid/sed OC	680	µg/kg	1.4	mg/kg OC	1,800	µg/kg	43	µg/kg	730	µg/kg bw/day
Total DDTs	11.2	tiss dw/sed dw	5.21	tiss lipid/sed OC	8,500	µg/kg	2.7	mg/kg OC	28,000	µg/kg	170	µg/kg	11,000	µg/kg bw/day

a EPC_{soil} was based on UCL concentration when the dataset had six or more detects. See Attachment 3 for summary statistics on EPCs.

c EPC_{soil} was based on UCL concentration when the dataset had six or more detects, except where noted. See Attachment 3 for summary statistics on EPCs.

c EPC_{invert} was estimated from EPC_{soil} and invertebrate BAF and converted to ww assuming a moisture content of 71%, and where EPC_{invert} (ww) = [BAF(dw/dw) x EPC_{soil}] x (1 – F_M), where F_M = fraction moisture. See Attachment 2 for details on selected BAFs and assumptions used to estimate prey tissue concentrations.

d $EPC_{aquatic\ invert}$ estimated from EPC_{sed} (as a dw concentration or an OC-normalized concentration) and aquatic benthic invertebrate BSAF. When the sediment EPC was dw, the following equation was used: $C_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x (1 – F_M), where F_M = fraction moisture. When the sediment EPC was OC-normalized, the following equation was used: $EPC_{aquatic\ invert}$ (ww) = (BSAF x EPC_{sed}) x F_L, where F_L = fraction lipid. $EPC_{aquatic\ invert}$ was converted to ww assuming a moisture content of 79%or a lipid content of 1.2%. See Attachment 2 for details on selected BSAFs and assumptions used to estimate prey tissue concentrations.

e $Dose_{diet}$ was calculated using Equations 3-1 and 3-5, exposure parameters presented in Table 3-8, and assumption that diet is composed of 70% terrestrial invertebrates (30% earthworms and 40% other terrestrial invertebrates) and 30% aquatic invertebrates.

f $Dose_{diet}$ was calculated assuming 100% terrestrial prey (no sediment data available to model aquatic prey)

g EPC_{sed} is based on the maximum detected concentration because the UCL concentration was greater than the maximum concentration (see Attachment 3).

BAF – bioaccumulation factor
BSAF – biota-sediment accumulation factor
bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
na – not applicable (not analyzed in Force Lake sediment)
OC – organic carbon
UCL – upper confidence limit on the mean
ww – wet weight

4.0 EFFECTS ASSESSMENT

This section describes how effects thresholds (i.e., water, sediment, and tissue-residue, or dietary-dose TRVs) were developed for each of the ecological ROCs. Effects thresholds were integrated with the exposure data (Section 3.0) in the risk characterization (Section 5.0) to determine HQs. Uncertainties are discussed in Section 6.0.

4.1 Invertebrates

Sediment and surface water thresholds were developed to estimate risks to aquatic benthic invertebrates. Soil thresholds were developed to estimate risks to terrestrial invertebrates. The following subsections present the sediment and soil thresholds.

4.1.1 Sediment TRVs

Effects on the aquatic benthic invertebrate community were assessed by comparing the refined COPC concentrations in sediment from Force Lake to literature-based sediment TRVs that are protective of aquatic benthic invertebrates. To be conservative, the lower of the TEL reported by Smith et al. (1996) and the TEC reported by MacDonald et al. (2000) was selected as the sediment TRV for each refined COPC. TELs identify concentrations below which adverse effects on sediment-dwelling organisms are not expected; they do not necessarily predict toxicity (NOAA 1999). Similarly, TECs provide a basis for predicting the absence of sediment toxicity (MacDonald et al. 2000). Therefore, to better understand if there is a potential for adverse effects on sediment-dwelling organisms, surface sediment concentrations were also compared to the lower of PELs reported by Smith et al. (1996) and the PEC reported by MacDonald et al. (2000). Refined COPC concentrations that exceed PELs or PECs indicate probable effects on sediment-dwelling organisms, although these generic benchmarks do not take into account site-specific bioavailability (e.g., high TOC content in the lake sediments).

Selected sediment TRVs for all sediment refined COPCs are presented in Table 4-1.

Table 4-1. Selected Sediment TRVs

Refined Sediment COPC	PEL or PEC[a]	TEL or TEC[b]	Source
Metals (mg/kg dw)			
Cadmium	3.53	0.596	Smith et al. (1996)
Copper	149	31.6	MacDonald et al. (2000)
Lead	91.3	35	Smith et al. (1996)
Nickel	36	18	Smith et al. (1996)
Zinc	315	121	MacDonald et al. (2000) [TEC]; Smith et al. (1996) [PEL]
PAHs (µg/kg dw)			
Fluoranthene	2,230	111	Smith et al. (1996) (TEL); MacDonald et al. (2000) (PEC)
Phenanthrene	515	41.9	Smith et al. (1996)
PCBs (µg/kg dw)			
Total PCBs	277	34.1	Smith et al. (1996)
Pesticides (µg/kg dw)			
2,4′-DDD	8.51	3.54	Smith et al. (1996)
4,4′-DDD	8.51	3.54	Smith et al. (1996)
4,4′-DDE	6.75	1.42	Smith et al. (1996)
Total DDTs	572	5.28	MacDonald et al. (2000)

[a] The PEL or PEC is presented, whichever is lower in concentration.
[b] The TEL or TEC is presented, whichever is lower in concentration.

COPC – contaminant of potential concern
dw – dry weight
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probably effects concentration
PEL – probable effects level
TEC – threshold effects concentration
TEL – threshold effects level
TRV – toxicity reference value

4.1.2 Soil TRVs

Effects on the terrestrial invertebrate community were assessed by comparing the refined COPC concentrations in wetland soils with literature-based soil TRVs that are protective of invertebrates. Soil TRVs were selected as the lowest threshold from the following sources:

- EPA ecological SSLs protective of soil invertebrates (2007b)
- ORNL soil data for earthworms (Efroymson et al. 1997)
- DEQ soil screening-level values protective of terrestrial invertebrates (2001)

All of these soil TRVs are intended to be used as conservative screening thresholds and, therefore, may overestimate risks to terrestrial invertebrates. For example, ecological SSLs are derived to avoid underestimating risk (EPA 2007b). Both DEQ (2001) and EPA (2007b) state that reported soil thresholds are generally not appropriate for use as site-specific cleanup levels. Efroymson et al. (1997) states that site-specific considerations should be evaluated in addition to the comparison of soil concentrations to these thresholds because if an ORNL benchmark is exceeded by background (for metals) or reference area (for organic compounds)[24] soil concentrations, it is generally safe to assume that the benchmark is a poor measure of risk to terrestrial invertebrates (i.e., earthworms) at that site. Regional background or reference area concentrations are presented in Table 4-2. The uncertainty of the application of these conservative soil TRVs to estimate risks to terrestrial invertebrates is discussed further in the uncertainty analysis of the risk characterization (Section 5.1.2). Selected soil TRVs for all soil refined COPCs are presented in Table 4-2.

Table 4-2. Selected Ecological Soil Thresholds

Refined Soil COPC	Unit (dw)	Soil TRV	Soil TRV Source	Soil Background or Reference Area Concentration[a]
Metals				
Chromium	mg/kg	2[b]	DEQ (2001); Efroymson et al. (1997)	42
Copper	mg/kg	50	DEQ (2001); Efroymson et al. (1997)	36
Mercury	mg/kg	0.5[c]	DEQ (2001); Efroymson et al. (1997)	0.07
Zinc	mg/kg	120	Ecological SSL (EPA 2007e)	86
PAHs				
Total HPAHs	µg/kg	18,000	Ecological SSL (EPA 2007c)	54 – 388

a Details regarding the sources of soil background and reference area values are provided in Attachment 4. Concentrations for metals are representative of background concentrations and concentrations for organic compounds are representative of reference area concentrations.

b The soil TRV for chromium (0.4 mg/kg dw) as reported in DEQ (2001) and Efroymson et al. (1997) was determined from the LOEC of 2 mg/kg dw using a safety factor of 5. Per consultation with EPA, safety factor-adjusted TRVs are not recommended; therefore, the selected soil TRV reflects the non-adjusted LOEC of 2 mg/kg dw.

c The soil TRV for mercury (0.1 mg/kg dw) as reported in DEQ (2001) and Efroymson et al. (1997) was determined from the LOEC of 0.5 mg/kg dw using a safety factor of 5. Per consultation with EPA, safety factor-adjusted TRVs are not recommended; therefore, the selected soil TRV reflects the non-adjusted LOEC of 0.5 mg/kg dw.

COPC – contaminant of potential concern
dw – dry weight
DEQ – Oregon Department of Environmental Quality
EPA – US Environmental Protection Agency
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LOEC – lowest-observed-effect concentration
PAH – polycyclic aromatic hydrocarbon
SSL – soil screening level
TRV – toxicity reference value

[24] The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA.

4.2 Fish

The following section presents the TRVs that were developed for all fish tissue and dietary refined COPCs. A comprehensive literature search, following the approach outlined in Section 2.6.3, was conducted to identify published toxicity studies to date to determine appropriate toxicity studies for the development of fish tissue-residue TRVs.

4.2.1 Tissue-Residue TRVs

Tissue-residue TRVs were developed for the only tissue-residue refined COPC identified, total PCBs. This section presents a summary of the toxicity studies reviewed and the NOAEL and LOAEL TRVs. The LOAEL TRV was selected as the lowest concentration at which an adverse effect occurred that met the criteria presented in Section 2.6.3.2 and the NOAEL TRV was selected based on the selection criteria discussed in Section 2.6.3.2.

Twenty-one papers on the potential adverse effects of PCB mixtures on fish were reviewed (Table 4-3). Concentrations in whole-body fish tissue were reported in 17 of these studies, and concentrations in fish eggs or embryos were reported in four studies, as shown in Table 4-3. NOAEL and LOAEL concentrations in eggs and embryos are presented separately from whole-body NOAELs and LOAELs inasmuch as they are not directly comparable to adult whole-body tissue concentrations because they represent different life stages. These studies were not selected as TRVs but are discussed below and in the uncertainty analysis of the risk characterization section (Section 5.2).

Table 4-3. PCB Critical Tissue-Residue Toxicity Studies for Fish

Chemical Form	Test Species	Tissue Analyzed	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Route and Duration	Endpoint: Effect	Source
Studies Reporting Whole-Body NOAELs and LOAELs							
Aroclor 1260	common barbel	whole body	nv	**520**[a]	maternal exposure for 50 days	reproduction: reduced fecundity	Hugla and Thome (1999)
Aroclor 1254	juvenile Chinook salmon	whole body	980	nv	17 mg/kg ww in food for 4 weeks	survival/growth: no effect on growth or survival	Powell et al. (2003)
Aroclor 1260	common barbel	whole body	520	2,640	maternal exposure for 75 days	reproduction: lack of spawning in first reproductive season; egg and larval mortality	Hugla and Thome (1999)
Aroclor 1254	rainbow trout (14 weeks)	whole body	8,000	nv	15 mg/kg dw food for 32 weeks	survival/growth: no effect on growth or survival	Lieb et al. (1974)
Aroclor 1254	sheepshead minnow (adult)	whole body	1,900	9,300	maternal exposure to 0.32 µg/L in water for 28 days	reproduction: decreased fry survival in the first week after hatch	Hansen et al. (1974a)
Aroclor 1254	pinfish	whole body	nv	14,000	5 µg/L in water for 20 days	survival: reduced survival	Hansen et al. (1971)
Aroclor 1242	channel catfish	whole body	nv	14,300	20 mg/kg dw food for 20 weeks	survival/growth: 40% reduction in body weight gain	Hansen et al. (1976)
Aroclor 1268	mummichog (adult)	whole body	15,000	nv	15 µg/g in food for 6 weeks	reproduction: no effect on fertilization, hatching, or larval survival	Matta et al. (2001)
Clophen A50	*Phoxinus phoxinus* (minnow)	whole body	nv	25,000	200 µg/g food for 45 days; observation for 355 additional days	reproduction: increased fry mortality; delayed spawning	Bengtsson (1980)
Aroclor 1254	spot	whole body	27,000	46,000	1 and 5 µg/L in water for 20 days	survival: reduced survival	Hansen et al. (1971)
Aroclor 1248, 1260 mixture	fathead minnow	whole body	25,000	50,000	0.1 and 0.4 µg/L for 30 days	reproduction: reduced weight of second-generation fish at 30 days	DeFoe et al. (1978)
Aroclor 1254	brook trout embryos	whole body	31,000	71,000	0.69 and 1.5 µg/L water for 128 days (10 days prior to hatch and 118 days after)	survival: reduced fry growth	Mauck et al. (1978)

Table 4-3. PCB Critical Tissue-Residue Toxicity Studies for Fish

Chemical Form	Test Species	Tissue Analyzed	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Route and Duration	Endpoint: Effect	Source
Aroclor 1016	sheepshead minnow	whole body	110,000	nv	10 µg/L in water for 4 weeks	reproduction: no effect on fertilization success, survival of embryos, or fry survival	Hansen et al. (1975)
Aroclor 1016	pinfish	whole body	nv	106,000	21 µg/L in water for 33 days	survival: 50% mortality	Hansen et al. (1974b)
Aroclor 1254: 1260 mixture	juvenile rainbow trout	whole body	120,000	nv	2.9 µg/L in water for 90 days	survival: no effect on survival	Mayer et al. (1985)
Aroclor 1254: 1260 mixture	juvenile rainbow trout	whole body	70,000	120,000	1.5 and 2.9 µg/L in water for 90 days	growth: reduced growth	Mayer et al. (1985)
Aroclor 1254	brook trout embryos	whole body	71,000	125,000	1.5 and 3.1 µg/L water for 128 days (10 days prior to hatch and 118 days after)	survival: reduced fry survival	Mauck et al. (1978)
Aroclor 1016	sheepshead minnow fry	whole body	57,000	200,000	10 and 32 µg/L in water for 4 weeks	survival: reduced fry survival	Hansen et al. (1975)
Clophen A50	goldfish	whole body	nv	250,000	4,000 µg/L in water for 5 to 21 days	survival: reduced survival	Hattula and Karlog (1972)
Aroclor 1254	fathead minnow	whole body	nv	429,000 (female)	1.8 µg/L in water for 8 months	reproduction: reduced spawning	Nebeker et al. (1974)
Aroclor 1242, 1254, or 1260	fathead minnow (6 months)	whole body	nv	1,860 – 749,000	0.006 to 0.54 µmol/L in water for100 to 300 hours	survival: range of lethal body burdens (concentration associated with mortality of individuals)	van Wezel et al. (1995)
Studies Reporting Only Egg and Embryo NOAELs and LOAELs							
1:1:1:1 Aroclor 1016, 1221, 1254, 1260 mixture	Atlantic salmon	embryo	nv	857	embryos exposed to 625 µg/L PCB in water for 48 hours and observed through fry stage	reproduction: reduced fry body weight	Fisher et al. (1994)
Aroclor 1254	rainbow trout	embryos	nv	1,640	maternal exposure to 200 mg/kg in food for 60 days	reproduction: reduced fry growth in offspring	Hendricks et al. (1981)
Aroclor 1254	Atlantic croaker	egg	nv	3,200	maternal transfer	reproduction: reduced larval growth	McCarthy et al. (2003)
Aroclor 1254	brook trout	embryo	nv	77,900	200 µg/L in water for 21 days	reproduction: reduced hatchability (75%)	Freeman and Idler (1975)

[a] Tissue concentrations were converted from dry weight to wet weight assuming 20% solids.

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

nv – no value (no effects were observed at any tissue concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL])

PCB – polychlorinated biphenyl

TRV – toxicity reference value

UF – uncertainty factor

ww – wet weight

Bold identifies the LOAEL selected as the TRVs. A NOAEL TRV was not available from the study in which the chronic LOAEL of 520 µg/kg ww was reported, so it was estimated using a UF of 5. The resulting NOAEL TRV was 104 µg/kg ww.

Critical tissue PCB concentrations were reported in the toxicological studies reviewed for the selection of TRVs for 16 species (i.e., Atlantic croaker, Atlantic salmon, brook trout, channel catfish, Chinook salmon, common barbel, fathead minnow, goldfish, minnow (*Phoxinus phoxinus*), mummichog, pinfish, rainbow trout, sheepshead minnow, and spot). Adverse effects reported in the toxicological studies reviewed included reduced body weight; mortality; reduced early life stage or fry growth and survival; and reduced fecundity, hatchability, and spawning success following exposure to PCBs via diet, water, or maternal transfer to eggs. Table 4-3 presents a summary of the critical tissue-residue NOAELs and LOAELs reported for PCBs in these studies.

Whole-body effect-level concentrations ranged over three orders of magnitude across the fish species included in the toxicological studies reviewed. Whole-body tissue LOAELs ranged from 520 µg/kg ww for reduced barbel fecundity (Hugla and Thome 1999) to 429,000 µg/kg ww for reduced spawning in fathead minnows (Nebeker et al. 1974).

In the study reporting the lowest LOAEL, Hugla and Thome (1999) exposed 3-to-5-year-old common barbel from the University of Liege hatchery to 2,500 µg/kg PCBs in food for 50 days or to 12,500 µg/kg PCBs in food for 75 days (nominal concentrations) and analyzed effects on reproduction. Fish were reared at elevated temperatures (Leroy 2007 [pers. comm.]). Treatments were not replicated;16 fish in each treatment were exposed in a single tank. Spawning success was monitored in the first reproductive season, and fish were kept in PCB-free water for 1 year and evaluated for additional adverse effects. PCB concentrations in whole fish were reported following 50 or 75 days of exposure. In the first reproductive season, no spawning was reported at the high exposure level. No adverse effects were reported for the lower exposure level associated with the first reproductive season. One year following exposure, significant reductions in fecundity were reported at both exposure levels corresponding to whole-fish concentrations of 520 and 2,640 µg/kg ww for the low and high exposure levels, respectively. Mortality of eggs from the high dietary exposure group was close to 100% and was significantly higher than controls (which had a mean egg mortality of 52.4%), and egg and larval mortality significantly increased as PCB concentrations increased in eggs. At the lower dose, egg mortality was not significantly different from controls.

The LOAEL of 520 µg/kg ww associated with the fecundity endpoint was selected as the LOAEL TRV, although this effect level is uncertain because fecundity as measured after the first two spawning seasons was not dose responsive. Fecundity comparisons are complicated by the fact that the higher-dosed fish did not spawn during the first season and whole-body tissue concentrations were not measured 1 year later when the high-dose fish finally spawned. After the second spawning, average fecundity was similar between the high and low doses, but variance in fecundity was greater at the higher dose. In addition, the number of fish exposed at each treatment level and evaluated for effects is unclear. The effect of this uncertainty on risk calculations is discussed in the uncertainty section.

Whole-body NOAELs ranged from 980 µg/kg ww, at which no effect on growth or survival was reported in juvenile Chinook salmon (Powell et al. 2003), to 120,000 µg/kg ww for no effect on the survival of juvenile rainbow trout (Mayer et al. 1985). Because no NOAELs that were lower than the selected LOAEL of 520 µg/kg ww were identified, a NOAEL TRV of 104 µg/kg ww was estimated by applying a UF of 5 to the selected LOAEL TRV.

Effect concentrations reported in eggs and embryos ranged from 857 to 77,900 µg/kg ww in the four available studies. The lowest value was for reduced growth of Atlantic salmon fry held in PCB-free water for 176 days following exposure of eggs to aqueous PCB concentrations of 625 to 62,500 µg/L for 48 hours (Fisher et al. 1994). The highest value was for brook trout embryos exposed to 200 µg/L of PCBs in water for 21 days (Freeman and Idler 1975). NOAELs were not identified. Although these egg and embryo effects concentrations were generally lower than effects concentrations reported in the literature for more mature fish, egg/embryo and adult tissue-residue data are not directly comparable because they represent different life stages. Uncertainties associated with comparison of exposure concentrations to egg and embryo studies are discussed in the uncertainty analysis of the risk characterization section (Section 5.2).

4.2.2 Dietary-Dose TRVs

A comprehensive literature search, following the approach outlined in Section 2.6.3.4, was conducted to identify published toxicity studies to date to determine appropriate toxicity studies for the development of fish dietary-dose TRVs. Dietary fish TRVs were developed for the two refined COPCs identified for brown bullhead and pumpkinseed (i.e., cadmium and copper). Dietary-dose NOAEL and LOAEL TRVs were calculated from literature sources based on the reported no-effect and effect concentrations, body weight, and ingestion rates. This section presents a summary of the toxicity studies reviewed. LOAEL TRVs were selected as the lowest concentration at which an adverse effect occurred that met the criteria presented in Section 2.6.3.2 and the NOAEL TRVs were selected based on the selection criteria discussed in Section 2.6.3.2.

4.2.2.1 Cadmium

Nine studies that measured the effects of dietary cadmium on fish were evaluated for TRV selection (Table 4-4). Adverse effects on fish at various life stages were reported (i.e., fry, juvenile, and adult); effects included reduced survival, reduced growth, reduced fry production, and reduced fry survival. Table 4-4 summarizes the feeding rate assumptions, dietary-dose calculations, and dietary NOAELs and LOAELs for cadmium based on the reviewed literature.

Table 4-4. Cadmium Dietary Toxicity Studies for Fish

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Conditions	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg)	Lowest Effect Conc. in Diet (mg/kg)	Body Weight (kg)	Ingestion Rate (kg/day)	Source
Cadmium nitrate	rockfish (juvenile)	nv	0.010	fed prepared diet for 60 days	growth: reduced body weight and length, growth rate, and condition factor	nv	0.5 (dw)	0.0247	0.000494 (dw)	Kim et al. (2004); Kang et al. (2005)
Cadmium chloride	guppy (adult)	1.2	nv	fed midge larvae daily for 2 months	reproduction: no effect on number of live fry, fry survival, or premature release of embryos	28 (ww)[a]	nv	0.000859	0.0000372 (ww)	Hatakeyama and Yasuno (1987)
Cadmium chloride	guppy (60 days old)	1.6	nv	fed midge larvae daily for 30 days	growth: no effect on body weight	37 (ww)[a]	nv	0.000859	0.0000372 (ww)	Hatakeyama and Yasuno (1987)
Cadmium nitrate	rockfish	2.5	nv	fed prepared diet daily for 60 days	survival: no effect on survival	125 (dw)	nv	0.0247	0.000494 (dw)	Kim et al. (2004)
Cadmium chloride	guppy (30 days old)	**3.2**	**4.6**	fed live midge larvae daily for 7 months	reproduction: reduced cumulative number of fry produced	68 (ww)[a]	106 (ww)[a]	0.000779 (NOAEL) 0.000859 (LOAEL)	0.0000372 (ww)	Hatakeyama and Yasuno (1987)
Cadmium chloride	rainbow trout	4.1	nv	fed of live brine shrimp daily for 60 days[b]	survival: no effect on survival	69 (dw)	nv	0.000611	0.00037 (dw)	Mount et al. (1994)
Cadmium nitrate	rainbow trout	5.9	nv	fed prepared diet daily for 15 to 30 days	growth/survival: no effect on specific growth rate, survival	294 (dw)	nv	0.01704	0.000341 (dw)	Baldisserotto et al. (2005)
Cadmium chloride	guppy	1.0	nv	fed *Moina macrocoipa* daily for 10 to 30 days	growth: no effect on growth[c]	23 (ww)[a]	nv	0.000859 (Hatakeyama and Yasuno 1987)	0.0000372 (ww) (Hatakeyama and Yasuno 1987)	Hatakeyama and Yasuno (1982)
Cadmium nitrate	rainbow trout	9.4	nv	fed prepared diet daily for 28 days	growth/survival: no effect on growth rate or survival	471 (dw)	nv	0.019	0.000380 (dw)	Franklin et al. (2005)

Table 4-4. Cadmium Dietary Toxicity Studies for Fish

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Conditions	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg)	Lowest Effect Conc. in Diet (mg/kg)	Body Weight (kg)	Ingestion Rate (kg/day)	Source
Cadmium chloride	guppy (30 days old)	nv	9.4	fed live midge larvae daily for 7 months	growth/survival: reduced female growth and survival	nv	170 (ww)[a]	0.000659	0.0000364 (ww)	Hatakeyama and Yasuno (1987)
Cadmium nitrate	rainbow trout (juvenile)	16	28	fed prepared diet daily for 36 days	survival: reduced survival	786 (dw)	1,395 (dw)	0.005	0.00010 (dw)	Szebedinsky et al. (2001)
Cadmium sulfate	rainbow trout (juvenile)	nv	68	fed prepared diet daily for 28 days	survival: reduced survival	nv	10,000 (dw)	0.131	0.00089 (dw)	Handy (1993b)

Note: The dietary dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate was not presented in the study, a citation or information about the source is provided.

[a] Wet-weight concentration was calculated from dry-weight concentration based on 86.7% moisture reported in midge larvae.

[b] Fish were exposed to cadmium in both water and the diet.

[c] A significant effect on growth was observed at day 10; however, growth was recovered by day 20.

bw – body weight

dw – dry weight

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any tissue concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

TRV – toxicity reference value

UF – uncertainty factor

ww – wet weight

Bold identifies the NOAEL and LOAEL selected as dietary TRVs.

Dietary-dose LOAELs ranged from 0.01 mg/kg bw/day for growth of juvenile rockfish (Kang et al. 2005; Kim et al. 2004) to 68 mg/kg bw/day for mortality of rainbow trout (Handy 1993b). Dietary NOAELs ranged from 2.5 mg/kg bw/day for mortality of juvenile rockfish (Kang et al. 2005; Kim et al. 2004) to 29 mg/kg bw/day for reproduction of guppy (Hatakeyama and Yasuno 1987). The lowest LOAEL of 0.010 mg/kg bw/day based on growth of juvenile rockfish (Kang et al. 2005; Kim et al. 2004) was associated with high uncertainty. This LOAEL was two to three orders of magnitude lower than the NOAELs reported in the eight other studies (which ranged from 1.0 to 16 mg/kg bw/day) and was three to four orders of magnitude lower than the LOAELs reported in the three other studies that reported LOAELs (which ranged from 4.6 to 68 mg/kg bw/day). In addition, the toxic effects associated with the lowest LOAEL (0.0101 mg/kg bw/day) are uncertain because in one of the two papers in which the study is reported (Kim et al. 2004), the observed growth effect is partially attributed to reduced food intake, which may be to the result of food avoidance rather than toxicological effects. Due to the uncertainty associated with this study, the next lowest LOAEL of 4.6 mg/kg bw/day, based on guppy reproduction was selected as the LOAEL TRV for cadmium (Hatakeyama and Yasuno 1987). The NOAEL of 3.2 mg/kg bw/day reported in this study was selected as the NOAEL TRV for cadmium. Hatakeyama and Yasuno (1987) fed midge larvae that had been exposed to cadmium chloride to 30-day-old guppies for 7 months. The number of fry produced was reduced in fish fed 4.6 mg/kg bw/day but was unaffected in fish fed 3.2 mg/kg bw/day.

4.2.2.2 Copper

Thirteen toxicity studies that exposed fish to dietary copper were evaluated for TRV selection (Table 4-5). Adverse effects on growth or survival were reported in four species (Atlantic salmon, channel catfish, rainbow trout, and grey mullet) following exposure to dietary copper. Table 4-5 summarizes the food ingestion rate assumptions, dietary dose calculations, and dietary NOAELs and LOAELs for copper reported in the reviewed literature.

Table 4-5. Copper Dietary Toxicity Studies for Fish

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Conditions	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg dw)	Lowest Effect Conc. in Diet (mg/kg dw)	Body Weight (kg)	Food Ingestion Rate (kg dw/day)	Source
Copper sulfate	channel catfish (fingerling)	0.24	0.48	fed prepared diet daily for 16 weeks	growth: reduced growth	8	16	0.046 (NOAEL) 0.036 (LOAEL)	0.00137 (NOAEL) 0.00108 (LOAEL) (Murai and Andrews 1978)	Murai et al. (1981)
Copper sulfate	rockfish (juvenile)	**1.0**	**2.0**	fed prepared diet for 60 days	growth: reduced growth rate	50	100	0.026	0.00052	Kang et al. (2005)
Copper sulphate	rainbow trout	2.2	nv	fed prepared diet for 32 days	survival: no effect on survival	200	na	0.14	0.0015	Handy (1992)
Copper sulphate pentahydrate	rainbow trout	6.8	nv	fed prepared diet for 16 weeks	growth: no effect on growth	287	na	0.014	0.00034	Lanno et al. (1985b)
Copper sulfate	rainbow trout	13	nv	fed prepared diet for 42 days	growth: no effect on growth	684	na	0.016	0.00030[a]	Miller et al. (1993)
Copper sulphate pentahydrate	Atlantic salmon (parr)	17	nv	fed prepared diet for 4 weeks	growth: no effect on body weight, length, or condition factor	500	na	0.072	0.0018	Berntssen et al. (1999b)
Copper sulphate pentahydrate	rainbow trout	17	nv	fed prepared diet for 24 weeks	survival/growth: no effect on growth or survival	691.3	na	0.013	0.00029	Lanno et al. (1985b)
Copper sulphate pentahydrate	rainbow trout	18	nv	fed prepared diet for 8 weeks	survival: no effect on survival	730	na	0.0075	0.00019	Lanno et al. (1985b)
Copper sulphate pentahydrate	rainbow trout	nv	18	fed prepared diet for 8 weeks	growth: reduced growth	na	730	0.0075	0.00019	Lanno et al. (1985b)
Copper sulphate pentahydrate	rainbow trout	nv	20	fed prepared diet for 16 weeks	growth: reduced growth[b]	na	796	0.0091	0.00021	Lanno et al. (1985a)
Cu sulfate pentahydrate	Atlantic salmon (fry)	14	20	fed prepared diet for 3 months	growth: reduced growth	na	700	0.0041	0.0001134[c]	Lundebye et al. (1999)
Copper sulphate	Atlantic salmon	20	28	fed prepared diet for 3 months	growth: reduced growth	638	868	0.0048	0.00015	Berntssen et al. (1999a)
Copper sulphate pentahydrate	rainbow trout	42	nv	fed prepared diet for 28 days	survival/growth: no effect on growth or survival	1,042	na	0.0535	0.0021	Kamunde et al. (2001)
Copper chloride	rainbow trout (fry)	26[d]	50[d]	fed brine shrimp for 60 days	survival: reduced survival	440	830	0.00073	0.000044	Mount et al. (1994)

Table 4-5. Copper Dietary Toxicity Studies for Fish

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Conditions	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg dw)	Lowest Effect Conc. in Diet (mg/kg dw)	Body Weight (kg)	Food Ingestion Rate (kg dw/day)	Source
Copper chloride	rainbow trout (fry)	60[d]	nv	fed brine shrimp for 60 days	growth: no effect on body weight and length	1,000	na	0.00060	0.000036	Mount et al. (1994)
Copper sulphate pentahydrate	grey mullet	nv	60	fed prepared diet for 67 days	growth: reduced growth[e]	na	2,400	0.016	0.0004	Baker et al. (1998)
Copper sulphate	rainbow trout	69	nv	fed prepared diet for 28 days	survival: no effect on survival	10,000	na	0.13	0.00091	Handy (1993b)

Note: The dietary dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary dose-TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate was not presented in the study, a citation or information about the source is provided.

[a] Food ingestion rate was estimated as 1.9% body weight per day based on the average feeding rate reported in 16 other dietary toxicological studies in which rainbow trout were fed a laboratory-prepared diet (i.e., not live prey) (Baldisserotto et al. 2005; Cockell and Bettger 1993; Cockell and Hilton 1988; Cockell et al. 1991, 1992; Franklin et al. 2005; Galvez and Wood 1999; Handy 1993a, b; Hendricks et al. 1985; Lanno et al. 1985a, b; Kamunde et al. 2001; Macek et al. 1970; Oladimeji et al. 1984; Rodgers and Beamish 1982).

[b] A significant reduction in growth was observed at 16 weeks; however, growth was recovered by 24 weeks.

[c] A feeding rate of 2.8% bw/day was assumed for Lundebye et al. (1999) based on the average feeding rate for Atlantic salmon fed synthetic diets in two toxicity studies (Berntssen et al. 1999a, b).

[d] Fish were exposed to copper in both water and diet.

[e] An observed reduction of growth was associated with a reduction in feeding.

bw – body weight

dw – dry weight

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

na – not applicable

nv – no value (No effects were observed at any tissue concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

TRV – toxicity reference value

Bold identifies the NOAEL and LOAEL selected as dietary TRVs.

Dietary-dose LOAELs ranged from 0.48 mg/kg bw/day for growth of channel catfish fed dietary copper for 16 weeks (Murai et al. 1981) to 60 mg/kg bw/day for growth of Atlantic salmon fry (Baker et al. 1998). Dietary NOAELs ranged from 0.24 mg/kg bw/day for growth of channel catfish (Murai et al. 1981) to 69 mg/kg bw/day for mortality of rainbow trout (Handy 1993b).

The lowest LOAEL and NOAEL calculated from the reviewed literature (0.48 and 0.24 mg/kg bw/day, respectively) were based on Murai et al. (1981). However, this study was not used in deriving the TRV for copper because of uncertainty in the results. In this study, a significant decrease in body weight was reported for channel catfish fingerlings exposed to 16 mg/kg dw of copper as copper sulfate in a prepared diet for 16 weeks compared with the control group, but a significant reduction in body weight was not observed in fish fed 8 mg/kg dw relative to controls. Furthermore, the sensitivity of channel catfish fingerlings documented by Murai et al. (1981) has not been confirmed in subsequent studies using similar exposures and fish of similar age (Erickson et al. 2003; Gatlin and Wilson 1986) and has been characterized as atypical by other studies of copper in fish (Lorentzen et al. 1998). Gatlin and Wilson (1986) attempted to reproduce the exposure conditions used by Murai et al. (1981) in a study with fingerling catfish that were larger (body weight = 5.5 g) than those used in Murai et al. (1981) (body weight = 1 g). Gatlin and Wilson (1986) reported no difference in weight gain in their highest dietary exposure of 40 mg/kg dw. Likewise, Erickson et al. (2003)[25] reported no differences in weight gain following exposure for 30 days to copper-contaminated prey at dietary concentrations of 157 and 246 mg/kg dw using much smaller fingerling channel catfish (0.2 g/fish). These studies help bracket the size of fingerlings tested and confirm that the Murai et al. (1981) study results are anomalous.

The next lowest LOAEL was presented in Kang et al. (2005). In that study, juvenile rockfish were exposed to 50, 100, 250, or 500 mg/kg dw of copper as copper sulfate for 60 days. Significant effects on growth (identified as body weight growth rate) were reported for fish exposed to dietary concentrations of 100 mg/kg dw or greater (i.e., a dose of 2.0 mg/kg bw/day). No adverse effects were observed in fish exposed to 50 mg/kg dw in the diet (i.e., a dose of 1.0 mg/kg bw/day). The NOAEL and LOAEL of 1.0 and 2.0 mg/kg bw/day, respectively, were thus selected as the NOAEL and LOAEL TRVs.

[25] Erickson (2003) is currently under review for publication but has not yet been published and was not included in the studies evaluated for TRV derivation.

4.2.2.3 Summary of Fish Dietary TRVs

Table 4-6 summarizes the selected NOAEL and LOAEL TRVs for all fish dietary refined COPCs.

Table 4-6. Selected Fish Dietary TRVs

Refined COPC	Formula-tion	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint: Effect	Source
Cadmium	cadmium chloride	guppy	3.2	4.6	reproduction: reduced no. of fry produced	Hatakeyama and Yasuno (1987)
Copper	copper sulfate	juvenile rockfish	1.0	2.0	growth: reduced growth rate	Kang et al. (2005)

bw – body weight
COPC – contaminant of potential concern
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
TRV – toxicity reference value
UF – uncertainty factor

4.3 Birds

A comprehensive literature search, following the approach outlined in Section 2.6.4.2, was conducted to identify published toxicity studies to date to determine appropriate toxicity studies for the development of bird dietary-dose TRVs. Dietary bird TRVs were developed for the two refined COPCs identified for red-tailed hawk, ruddy duck, and/or great blue heron (i.e., mercury and total DDTs). Dietary-dose NOAEL and LOAEL TRVs were calculated from literature sources based on the reported no-effect and effect concentrations, body weight, and ingestion rates. This section presents a summary of the toxicity studies reviewed. LOAEL TRVs were selected as the lowest concentration at which an adverse effect occurred that met the criteria presented in Section 2.6.3.2 and the NOAEL TRVs were selected based on the selection criteria discussed in Section 2.6.3.2.

4.3.1 Mercury

Chronic effects of dietary mercury on birds include adverse effects on growth, development, reproduction, metabolism, and behavior (Eisler 1987a). Six studies that evaluated the toxicity of dietary mercury to birds were identified (Table 4-7). In these studies, adverse effects on reproduction, early-life-stage growth, or adult survival from dietary exposure to mercury were reported for various bird species, including great egrets, Japanese quail, zebra finch, and bobwhite quail. LOAELs ranged from 0.091 mg/kg bw/day for reduced growth in young great egrets (Heinz 1980) to 62 mg/kg bw/day for offspring mortality of Japanese quail (Hill and Soares 1987). The lowest LOAEL of 0.091 mg/kg bw/day mercury was selected as the TRV.

Table 4-7. Mercury Dietary Toxicity Studies for Birds

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc.	Lowest Effect Conc.	Body Weight (kg)	Food Ingestion Rate	Source
Methyl-mercury chloride	great egret (1 day old)	nv	**0.091**	14 weeks	growth: reduced growth	nv	0.5 mg/kg ww	1.02 (Arizona Game & Fish 2002)	0.185 kg ww/day (Kushlan 1978)	Spalding et al. (2000)
Methyl-mercury chloride	mallard	0.50	nv	> 60 days	reproduction: no effect on eggshell thickness	5 mg/kg ww	nv	1.082 (Dunning 1993)	0.1082 kg ww/day (Heinz et al. 1987)	Heinz (1980)
Methyl-mercury chloride	Japanese quail (chicks)	nv	0.9	5 days	reproduction: reduced hatchling survival of offspring	nv	16 mg/kg ww[a]	0.1 (NRC 1994)	0.0053 kg dw/day, galliformes (Nagy 2001)	Hill and Soares (1987)
Methyl-mercury chloride	zebra finch	0.72	1.4	76 days	survival: reduced survival	2.5 mg/kg dw[b]	5 mg/kg dw[b]	0.012 (Dunning 1993)	0.0034 kg dw/day, passerines (Nagy 2001)	Scheuhammer (1988)
Methyl-mercury chloride	northern bobwhite quail (12 days old)	0.43	1.6	6 weeks	survival: reduced survival	5.4 mg/kg ww	20 mg/kg ww	0.19 (EPA 1993b)	0.0150 kg ww/day (EPA 1993b)	Spann et al. (1986)
Mercuric chloride	Japanese quail (1 day old)	0.80	1.6	10 weeks	reproduction: reduced eggshell thickness	4 mg/kg ww	8 mg/kg ww	0.155 (Edens and Garlich 1983)	0.031 kg ww/day (Edens and Garlich 1983)	Stoewsand et al. (1971)
Dimethyl mercury	American kestrel	5.24	nv	3 months	reproduction: no effect on eggshell thickness	10 mg/kg ww[c]	nv	0.13 (Pattee 1984)	0.0136 kg dw/day, Eurasian kestrel (Nagy 2001)	Peakall and Lincer (1972)
Mercuric chloride	Japanese quail (chicks)	nv	62	5 days	reproduction: reduced offspring hatchling survival	nv	1,045 mg/kg ww[a]	0.1 (NRC 1994)	0.0053 kg dw/day, galliformes (Nagy 2001)	Hill and Soares (1987)

Note: The dietary dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). Effect and no-effect concentrations are presented in the units given in the studies reviewed. Table notes indicate how units were converted to wet weight or dry weight to correspond to the food ingestion rate units for calculating NOAELs and LOAELs. Ingestion rates are from equations for bird groups presented in Nagy (2001), from data presented for individual bird species (Nagy 2001), or from other sources as noted.

[a] Effect concentration was converted into dry weight assuming 10% moisture in prepared diet.

[b] No-effect and effect concentrations were converted into wet weight assuming 10% moisture in prepared diet.

[c] Study did not indicate whether the mercury concentration in the diet, which consisted of dead chicks, was reported in wet weight or dry weight. It was assumed to be reported in wet weight and was converted into dry weight using 80% moisture content.

bw – body weight
dw – dry weight
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
NRC – National Research Council
nv – no value (No effects were observed at any tissue concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)
UF – uncertainty factor
ww – wet weight

Bold identifies the LOAEL selected as the TRV. A NOAEL TRV was estimated by dividing the chronic LOAEL TRV by a UF of 5. The resulting NOAEL TRV was 0.018 mg/kg bw/day.

NOAELs ranged from 0.43 mg/kg bw/day, at which there was no effect on the survival of young bobwhite quail (Spann et al. 1986), to 5.24 mg/kg bw/day, at which there was no effect on eggshell thickness in American kestrels (Peakall and Lincer 1972). None of these NOAELs were lower than the lowest LOAEL. Therefore, the chronic LOAEL was divided by a UF of 5 to obtain the NOAEL TRV of 0.018 mg/kg bw/day.

4.3.2 Total DDTs

The primary adverse effects of DDT, DDD, and DDE exposure on birds are related to reproduction, including eggshell thinning, egg breakage, embryo mortality, and death of young (Mendenhall et al. 1983; McLane and Hughes 1980; Lincer 1975). Exposure to DDT and its metabolites at relatively high concentrations may cause weight loss, neurotoxicity, and mortality (Stickel and Rhodes 1970). Toxicity studies with any form of DDT, including DDD and DDE, were evaluated to select the TRV for total DDTs. The evaluation identified numerous studies that analyzed the dietary toxicity of DDT, DDD, and DDE to birds. Table 4-8 presents the results from nine studies with the lowest reported effects concentrations. Additional studies on the toxicity of DDT in the diet resulted in NOAELs or LOAELs greater than 1 mg/kg bw/day but are not shown here (Peakall et al. 1975; Davison et al. 1976; Haegele and Hudson 1973, 1974; Pritchard et al. 1972; Risebrough and Anderson 1975; Lincer 1975; DeWitt 1956; Genelly and Rudd 1956; Scott 1977; Scott et al. 1975; Shellenberger 1978; Greichus and Hannon 1973). All of the reviewed studies evaluated reproduction endpoints; eight of the studies reported increased eggshell thinning. A dose of 0.15 mg/kg bw/day resulted in eggshell thinning in Japanese quail exposed to p,p′-DDT in the diet for 194 days. Although eggshell thinning was significantly different in the treated group than in controls, hatchability of the eggs was not affected. Therefore, it was concluded that the degree to which eggshell thinning was observed would not affect reproductive success. The next lowest dose of 0.32 mg/kg bw/day resulted in eggshell thinning, eggshell breakage, and nestling mortality in barn owls exposed to dietary p,p’-DDE for 2 years. This dose was selected as the LOAEL TRV for total DDTs because a clear impairment to reproductive success was observed. The only NOAEL below the LOAEL was a dose of 0.19 mg/kg bw/day, which did not cause eggshell thinning in mallards exposed to DDT for 11 months (Davison and Sell 1974). Because other reproduction endpoints were not assessed in this study, and it is unknown whether the no-effect level for eggshell thinning would be the same as the no-effect level for direct measures (e.g., hatchability, viability of offspring) of reproductive success, this NOAEL was not selected. Instead, the NOAEL TRV was estimated from the selected LOAEL TRV using a UF of 5, resulting in a NOAEL TRV of 0.064 mg/kg bw/day for total DDTs.

Table 4-8. DDT, DDD, and DDE Dietary Toxicity Studies for Birds

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet	Lowest Effect Conc. in Diet	Body Weight (kg)	Food Consumption Rate	Source
p,p'-DDT	quail	nv	0.15	194 days	reproduction: increased eggshell thinning	nv	2.5 mg/kg ww[a]	0.09 (Dunning 1993)	0.0048 kg dw/day, galliformes (Nagy 2001)	Stickel and Rhodes (1970)
p,p'-DDT	mallard	0.19	nv	11 months	reproduction: no effect on eggshell thinning	2 mg/kg ww	nv	1.19	0.115 kg ww/day	Davison and Sell (1974)
DDE	barn owl	nv	**0.32**	2 years	reproduction: increased eggshell thinning, eggshell breakage, and nestling mortality	nv	2.83 mg/kg ww[a]	0.5235 (Dunning 1993)	0.0539 kg dw/day, carnivores (Nagy 2001)	Mendenhall et al. (1983)
DDE	American kestrel	nv	0.35	14 days	reproduction: increased eggshell thinning	nv	3 mg/kg ww[a]	0.13 (Pattee 1984)	0.0136 kg dw/day, Eurasian kestrel (Nagy 2001)	Peakall et al. (1973)
Technical DDD	mallard	nv	0.90	2 years	reproduction: decreased hatchling survival and production	nv	10 mg/kg dw[a]	1.082 (Dunning 1993)	0.1082 kg ww/day (Heinz et al. 1987)	Heath et al. (1969)
p,p'-DDE	mallard	nv	0.90	2 years	reproduction: increased eggshell thinning and number of cracked eggs; reduced hatchling survival and production	nv	10 mg/kg dw[a]	1.082 (Dunning 1993)	0.1082 kg ww/day (Heinz et al. 1987)	Heath et al. (1969)
p,p-DDE	black duck	nv	1.0	7 months	reproduction: increased eggshell thinning and duckling mortality; reduced hatchability	nv	10 mg/kg ww	1.25 (Dunning 1993)	0.125 kg ww/day (Heinz et al. 1987)	Longcore and Samson (1973)
DDE	mallard	nv	1.0	30 days	reproduction: increased eggshell thinning	nv	10 mg/kg ww[a]	1.082 (Dunning 1993)	0.1082 kg ww/day (Heinz et al. 1987)	Kolaja (1977)
DDT	mallard	nv	1.0	30 days	reproduction: increased eggshell thinning	nv	10 mg/kg ww[a]	1.082 (Dunning 1993)	0.1082 kg ww/day (Heinz et al. 1987)	Kolaja (1977)
p,p'-DDE	American kestrel	nv	1.0	1 year (two clutches)	reproduction: increased eggshell thinning	nv	2.8 mg/kg ww[a]	0.13 (Pattee 1984)	0.0136 kg dw/day, Eurasian kestrel (Nagy 2001)	Wiemeyer and Porter (1970); Porter and Wiemeyer (1972)

Note: The dietary dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg).Effect and no-effect concentrations are presented in the units given in the studies reviewed. Table notes indicate how units were converted to wet weight or dry weight to correspond to the food ingestion rate units for calculating NOAELs and LOAELs. Ingestion rates are from equations for bird groups presented in Nagy (2001), from data presented for individual bird species (Nagy 2001), or from other sources as noted.

[a] Effect concentration was converted into dry weight assuming 10% moisture in prepared diet

bw – body weight
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
nv – no value (No effects were observed at any tissue concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)
TRV – toxicity reference value
UF – uncertainty factor
ww – wet weight

Bold identifies the NOAEL and LOAEL selected as the TRVs. A NOAEL TRV was not available from the study in which the chronic LOAEL of 0.32 mg/kg bw/day was reported, so it was estimated using a UF of 5. The resulting NOAEL TRV for total DDTs was 0.064 mg/kg bw/day.

4.3.3 Summary of Bird Dietary TRVs

Table 4-9 summarizes the selected NOAEL and LOAEL TRVs for all bird dietary refined COPCs.

Table 4-9. Selected Bird Dietary TRVs

Refined COPC	Formula-tion	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint: Effect	Source
Mercury	methyl-mercury chloride	great egret (1 day old)	0.018[a]	0.091	growth: reduced growth	Spalding et al. (2000)
Total DDT	DDE	barn owl	0.064[a]	0.32	reproduction: increased eggshell thinning, eggshell breakage, and nestling mortality	Mendenhall et al. (1983)

[a] NOAEL was estimated using a UF of 5 (chronic LOAEL to NOAEL).

bw – body weight

COPC – contaminant of potential concern

DDT – dichlorodiphenyltrichloroethane

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

TRV – toxicity reference value

UF – uncertainty factor

4.4 Mammals

A comprehensive literature search, following the approach outlined in Section 2.6.4.2, was conducted to identify published toxicity studies to date to determine appropriate toxicity studies for the development of mammal dietary-dose TRVs. Dietary mammal TRVs were developed for all refined COPCs identified for Eastern cottontail and/or shrew (i.e., arsenic, cadmium, cobalt, copper, lead, mercury, vanadium, zinc, total PAHs, total PCBs, and total DDTs). Dietary-dose NOAEL and LOAEL TRVs were calculated from literature sources based on the reported no-effect and effect concentrations, body weight, and ingestion rates. This section presents a summary of the toxicity studies reviewed. LOAEL TRVs were selected as the lowest concentration at which an adverse effect occurred that met the criteria presented in Section 2.6.3.2 and the NOAEL TRVs were selected based on the criteria discussed in Section 2.6.3.2.

4.4.1 Arsenic

Mammalian effects from chronic exposure to inorganic arsenic may include weakness, paralysis, conjunctivitis, dermatitis, decreased growth, liver damage, and developmental effects in offspring (Eisler 1988a). Early developmental stages are most sensitive to arsenic exposure. The NOAEL and LOAEL TRVs were selected from the only identified study that evaluated the toxicity of arsenic to mammals from dietary exposure (i.e., via food rather than drinking water or gavage[26]) (Table 4-10). In this study, female rats fed 5.4 mg/kg bw/day arsenic had reduced body weights following 2 years of exposure to sodium arsenite (Byron et al. 1967). The results of this study were not statistically evaluated, although the final body-weight range reported in rats fed 5.4 mg/kg bw/day (280.4 g ± standard error of 21.38 g) was lower than the final body-weight range of the control group (350.9 g ± standard error of 26.36 g). Growth appeared unaffected in rats exposed to 2.6 mg/kg bw/day (body weight at the end of the 2-year study was 322.4 g, with a standard error range of ± 21.38 g). Thus, the NOAEL and LOAEL TRVs derived from this study are 2.6 and 5.4 mg/kg bw/day, respectively.

[26] Other toxicity studies were reviewed, including Hughes (2002) and Golub et al. (1998) and the primary literature cited in these documents; however, no additional studies were found in which mammals were exposed to arsenic via dietary exposure in food only.

Table 4-10. Arsenic Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food Ingestion Rate (kg ww/day)	Source
Sodium arsenite	rat	**2.6**	**5.4**	2 years	growth: reduced female body weight	31.25	62.5	0.302 (NOAEL), 0.278 (LOAEL)	0.025 (NOAEL), 0.024 (LOAEL)	Byron et al. (1967)

Note: Data were not statistically evaluated. The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration in the diet, body weight, and food ingestion rate, as presented in the study, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg).

bw – body weight

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

ww – wet weight

Bold identifies the NOAEL and LOAEL selected as the TRVs.

4.4.2 Cadmium

Chronic exposure of laboratory mammals to cadmium may result in anemia, decrease in bone density, kidney damage, decreased body weight, neurotoxicity, and reproductive and developmental effects (ATSDR 1999). Four studies that evaluated the toxicity of dietary cadmium to mammals were identified for growth, reproduction, or survival endpoints (Table 4-11). In these studies, adverse effects on growth and reproduction of rats or shrews were reported following subchronic exposure to cadmium in food. The study with the lowest LOAEL exposed female rats to cadmium for 10 days during pregnancy, which resulted in reduced body weight at a dose of 13 mg/kg bw/day (Machemer and Lorke 1981) and no effect on body weight at a dose of 3.5 mg/kg bw/day. These NOAEL and LOAEL values of 3.5 and 13 mg/kg bw/day, respectively, were selected as TRVs for cadmium. However, it should be noted that the selected NOAEL and LOAEL values were based on the exposure of rats to cadmium. The toxicity of cadmium to shrew was evaluated in one study, for which both the NOAEL and LOAEL were calculated as 115 mg/kg bw/day, which is 33 times higher than the selected NOAEL and 9 times higher than the selected LOAEL, indicating considerable uncertainty regarding the toxicity of cadmium to shrew. However, to be conservative, the lower NOAEL and LOAEL based on rats were used in this ERA.

Table 4-11. Cadmium Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food Ingestion Rate (kg ww/day)	Source
Cadmium chloride	beagle dog	0.88	nv	3 months	growth: no effect on female body weight	30	nv	9.7	0.283	Loeser and Lorke (1977b)
Cadmium chloride	rat	3.0	nv	3 months	survival/growth: no effect on adult survival or growth	30	nv	0.179	0.018	Loeser and Lorke (1977a)
Cadmium chloride	rat	**3.5**	**13**	10 days (pregnancy)	growth: reduced maternal body weight	na	na	na	na	Machemer and Lorke (1981)
Cadmium chloride	rat	13	nv	10 days	survival/growth/ reproduction: no effect on adult survival; fertility, fetus weight, or fetus survival	na	na	na	na	Machemer and Lorke (1981)
Cadmium chloride	shrew	115	nv	12 weeks	growth: no effect on female body weight	na	na	na	na	Dodds-Smith et al (1992)
Cadmium chloride	shrew	nv	115	12 weeks	growth: reduced male body weight	na	na	na	na	Dodds-Smith et al (1992)
Cadmium (unspecified form)	rat	nv	189	12 weeks	growth/reproduction: reduced pup birth weight and adult body weight	nv	200	0.1715	0.1812	Pond and Walker (1975)

Note: If the dose was not calculated in the study, the dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration in the diet, body weight, and food ingestion rate as provided in the study, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg).

bw – body weight

LOAEL – lowest-observed-adverse-effect level

na – not applicable

NOAEL – no-observed-adverse-effect level

nv – no value (Values are not presented for the effect concentration in diet and the LOAEL if effects were not observed in the study. Values are also not presented for the no-effect concentrations in diet and NOAEL if the lowest concentration in the diet resulted in an effect.)

ww – wet weight

Bold identifies the NOAEL and LOAEL selected as the TRVs.

4.4.3 Cobalt

In laboratory studies, chronic exposure of mice and rats to cobalt has resulted in adverse effects on reproduction, development, growth, and survival (ATSDR 2004). In addition, cardiovascular, neurological, renal, and endocrine effects have been reported (ATSDR 2004). Three studies that evaluated the toxicity of dietary cobalt to mammals were identified for growth, reproduction, or survival endpoints (Table 4-12). In these studies, adverse effects on survival or growth of laboratory guinea pigs and rats were reported following subchronic exposure to cobalt in food. No chronic studies were available. The lowest dose at which effects were reported (1.0 mg/kg bw/day) was selected as the LOAEL TRV. This LOAEL resulted in reduced growth in rats exposed to cobalt for 4 weeks (Chetty et al. 1979). No NOAELs that were lower than the selected LOAEL TRV were available. Therefore, a NOAEL TRV was estimated by dividing the subchronic LOAEL TRV by a UF of 10, resulting in a NOAEL of 0.1 mg/kg bw/day.

Table 4-12. Cobalt Dietary Toxicity Studies for Mammals

Chemcial Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food Ingestion Rate (kg ww/day)	Source
Cobalt chloride	rat	nv	**1.0**	4 weeks	growth: reduced body weight	nv	10	0.187	0.018 (EPA 1993b)	Chetty et al. (1979)
Cobalt sulfate	guinea pig	nv	1.4	5 weeks	growth: reduced survival	nv	20[a]	0.50	0.035 (EPA 1993b)	Mohiudden et al. (1970)
Cobalt sulfate	guinea pig	1.4	nv	5 weeks	growth: no effect on body weight	20	nv	0.50	0.035 (EPA 1993b)	Mohiudden et al. (1970)
Cobalt chloride	rat	1.9	10	3 days	growth: reduced body weight	20	100[b]	0.196	0.019 (EPA 1993b)	Wellman et al. (1984)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

[a] Data were not statistically evaluated; 4 of 20 guinea pigs died at the LOAEL, and 1 of 20 guinea pigs died in the control group.

[b] Data were not statistically evaluated; there was reduced food intake at the LOAEL.

bw – body weight

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

UF – uncertainty factor

Bold identifies the LOAEL selected as the TRV. A NOAEL TRV was not available from the study in which the subchronic LOAEL of 1.0 mg/kg bw/day was reported, so it was estimated using a UF of 10. The resulting NOAEL TRV was 0.1 mg/kg bw/day.

4.4.4 Copper

High concentrations of copper in the diet of mammals may result in reduced growth and food intake, anemia, and degeneration of liver, kidney, brain, and muscle, often resulting in death (Eisler 1997). Three studies that evaluated the toxicity of copper to mammals from dietary exposure were identified for growth, reproduction, or survival endpoints (Table 4-13). Effects on reproduction, mortality, and growth were observed in mink, rats, and mice. LOAELs ranged from 26 mg/kg bw/day for reproduction of mink (Aulerich et al. 1982) to 467 mg/kg bw/day for growth of mice (NTP 1993). NOAELs ranged from 18 mg/kg bw/day for reproduction of mink (Aulerich et al. 1982) to 749 mg/kg bw/day for mortality and growth of mice (NTP 1993). In the study reporting the lowest LOAEL, 38% kit mortality (as compared to 12% in the control group) and reduced litter mass were reported in the offspring of adult mink fed 26 mg/kg bw/day dietary copper as copper sulfate following 1 year of exposure during a critical life stage (Aulerich et al. 1982). No effect was reported on mink reproduction following exposure to 18 mg/kg bw/day (Aulerich et al. 1982). The LOAEL and NOAEL of 26 and 18 mg/kg bw/day, respectively, derived from Aulerich et al. (1982) were selected as the TRVs for copper. However, it should be noted that the selected NOAEL and LOAEL values were based on exposure of mink to copper. The toxicity of copper to shrew was evaluated in one study that looked at effects on body weight (a different endpoint than that of the selected TRVs), from which a NOAEL of 267 mg/kg bw/day was calculated, which is 15 times higher than the selected NOAEL and 10 times higher than the selected LOAEL. However, because a different endpoint was used in the shrew study, the uncertainty regarding the selected TRVs is unknown.

Table 4-13. Copper Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Effect Endpoint	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food Ingestion Rate (kg ww/day)	Source
Copper sulfate	mink	**18**	**26**	357 days	reproduction: reduced kit survival and litter mass	110.5	160.5	0.18	1.071 (NOAEL) 1.088 (LOAEL) (Bleavins and Aulerich 1981)	Aulerich et al. (1982)
Copper sulfate	mink	43	nv	153 to 657 days	growth: no effect on body weight	260.5	nv	0.18	1.056	Aulerich et al. (1982)
Copper sulfate	rat	137	nv	13 weeks	survival: no effect on survival	na	na	na	na	NTP (1993)
Copper sulfate	rat	67	137	13 weeks	growth: reduced body weight	na	na	na	na	NTP (1993)
Copper sulfate	rat	93	197	2 weeks	growth: reduced body weight	na	na	na	na	NTP (1993)
Copper chloride	shrew	267	nv	weanlings for 12 weeks	growth: no effect on weight	na	na	na	na	Dodds-Smith et al.(1992)
Copper sulfate	rat	305	nv	2 weeks	survival: no effect on survival	na	na	na	na	NTP (1993)
Copper sulfate	mouse	467	nv	13 weeks	survival: no effect on survival	na	na	na	na	NTP (1993)
Copper sulfate	mouse	227	467	13 weeks	growth: reduced body weight	na	na	na	na	NTP (1993)
Copper sulfate	mouse	749	nv	2 weeks	survival/growth: no effect on survival or growth	na	na	na	na	NTP (1993)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

bw – body weight

LOAEL – lowest-observed-adverse-effect level

na – not applicable

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL].)

ww – wet weight

Bold identifies the NOAEL and LOAEL selected as the TRVs.

4.4.5 Lead

The exposure of mammals to high concentrations of lead in the diet has been reported to cause anemia, weight loss, muscle atrophy, paralysis, brain damage, mortality, and reproductive effects (Eisler 1988b). Two studies that evaluated the toxicity of lead to mammals from ingestion in food were identified for growth, reproduction, or survival endpoints (Table 4-14). Effects from lead exposure were observed in only one of the two studies. In this study, offspring of rats exposed for 2 years to 90 mg/kg bw/day had kidney damage and lower body weights than did the control group; no effect on offspring body weight or kidney function was observed in rats exposed to 11 mg/kg bw/day (Azar et al. 1973). The other study exposed continuing generations of mice to doses of up to 7.35 mg/kg bw/day with no observed reproductive effects in the second and third generations (Iavicoli et al. 2006). The LOAEL from the study by Azar et al. (1973) was selected as the LOAEL for lead (90 mg/kg bw/day). Following the TRV selection criteria in Section 2.6.3.2, the highest NOAEL below the selected LOAEL (11 mg/kg bw/day, based on Azar et al. [1973]) and based on the same endpoint as the selected LOAEL (i.e., reproduction) was selected.

Table 4-14. Lead Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food Ingestion Rate (kg ww/day)	Source
Lead acetate	mouse	7.35	nv	second and third generation through puberty	reproduction: no effect on litter size	40	nv	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Iavicoli et al. (2006)
Lead acetate	rat	**11**	**90**	2 years	reproduction: reduced offspring weight and kidney damage	141	1,130	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Azar et al. (1973)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg).

bw – body weight

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL].)

ww – wet weight

Bold identifies the NOAEL and LOAEL selected as the TRVs.

4.4.6 Mercury

The exposure of mammals to mercury has been reported to adversely affect reproduction, growth, development, behavior, blood and serum chemistry, motor coordination, vision, hearing, histology, and metabolism (Eisler 1987a). Three studies that evaluated the toxicity of dietary mercury to mammals were identified for growth, reproduction, and survival endpoints (Table 4-15). In these studies, adverse effects following the ingestion of mercury included mortality and depressed growth in laboratory rats and mink. At the lowest LOAEL, growth was significantly reduced in rats fed 0.0084 mg/kg bw/day of mercury as methylmercuric chloride for three generations (Verschuuren et al. 1976). Adverse effects on mink were reported at concentrations two orders of magnitude higher than the LOAEL reported for rats. Growth was significantly reduced, and mortality was observed in mink at a dietary dose of 0.25 mg/kg bw/day methylmercuric chloride (Wobeser et al. 1976) and 0.64 gm/kg bw/day methylmercury (Aulerich et al. 1974) for a subchronic duration. The lowest LOAEL, 0.0084 mg/kg bw, was selected as the LOAEL TRV. No NOAELs lower than the selected LOAEL TRV were available. Therefore, the NOAEL TRV was estimated by dividing the selected chronic LOAEL TRV by a UF of 5, resulting in a NOAEL TRV of 0.0017 mg/kg bw/day.

Table 4-15. Mercury Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. (mg/kg ww)	Lowest Effect Conc. (mg/kg ww)	Body Weight (kg)	Food IR (kg ww/day)	Source
Methylmercuric chloride	rat	nv	**0.0084**	three generations	growth: reduced growth	nv	0.0799	0.16	0.016 (EPA 1993b)	Verschuuren et al. (1976)
Methylmercuric chloride	rat	0.19	nv	three generations	survival/ reproduction: no effect on survival or reproduction	1.997	nv	0.20	0.019 (EPA 1993b)	Verschuuren et al. (1976)
Methylmercuric chloride	mink	0.16	0.25	93 days	survival/growth: reduced growth, 40% mortality	1.2	1.9[a]	1.34 (Bleavins and Aulerich 1981)	0.18 (Bleavins and Aulerich 1981)	Wobeser et al. (1976)
Methylmercury	mink	nv	0.64	2 months	survival/growth: reduced growth, 100% mortality	nv	5	1.2	0.15	Aulerich et al. (1974)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

[a] Two out of five mink died at the LOAEL.

bw – body weight

IR – ingestion rate

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

UF – uncertainty factor

ww – wet weight

Bold identifies the LOAEL selected as the TRV. A NOAEL TRV was not available from the study in which the chronic LOAEL of 0.0084 mg/kg bw/day was reported, so it was estimated using a UF of 5. The resulting NOAEL TRV was 0.0017 mg/kg bw/day.

4.4.7 Vanadium

Chronic exposure of mammals to vanadium may result in effects on the kidneys and on reproduction and development (ATSDR 1995). Two studies that evaluated the toxicity of vanadium to mammals from dietary exposure were identified for the growth, reproduction, and survival endpoints (Table 4-16). In the study with the lowest LOAEL, body weight was reduced in rats exposed to vanadium for 10 weeks at a dose of 2.7 mg/kg bw/day (Adachi et al. 2000). The other study exposed rats to 6.5 mg/kg bw/day, resulting in reduced offspring body weight and survival (Elfant and Keen 1987). The lowest LOAEL of 2.7 mg/kg bw/day was selected as the LOAEL TRV. No dietary NOAELs were identified, so the NOAEL TRV was estimated using a UF of 10 because the LOAEL was from a subchronic study, resulting in a NOAEL TRV of 0.27 mg/kg bw/day.

Table 4-16. Vanadium Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg)	Lowest Effect Conc. in Diet (mg/kg)	Body Weight (kg)	Food IR (kg/day)	Source
Sodium meta-vanadate	rat	nv	**2.7**	10 weeks	growth: reduced body weight	nv	50 (dw)	0.267	50 (dw)	Adachi et al. (2000)
Sodium meta-vanadate	rat	nv	6.5	reproductive period	survival/growth: reduced maternal body weight, offspring body weight gain and reduced survival	nv	75 (ww)	0.280	0.024 (ww) (EPA 1993b)	Elfant and Keen (1987)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

bw – body weight

IR – ingestion rate

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

UF – uncertainty factor

ww – wet weight

Bold identifies the LOAEL selected as the TRV. No NOAELs were identified, so the NOAEL TRV was estimated using a UF of 10 because the LOAEL was from a subchronic study. The resulting NOAEL TRV was 0.27 mg/kg bw/day.

4.4.8 Zinc

Adverse effects on mammals from excessive zinc in the diet include reduced survival, as well as a variety of neurological, hematological, immunological, hepatic renal, cardiovascular, developmental, and genotoxic effects (ATSDR 2005). Three studies that evaluated the toxicity of dietary zinc to mammals were identified for growth, reproduction, and survival endpoints (Table 4-17). In these studies on rats and ferrets, LOAELs ranged from 320 to 799 mg/kg bw/day. The lowest LOAEL resulted in reproductive effects in rats exposed during gestation (Schlicker and Cox 1968) and was selected as the LOAEL TRV (320 mg/kg bw/day). The highest NOAEL below the LOAEL with the same endpoint (160 mg/kg bw/day) was associated with the same study and was selected as the NOAEL TRV.

Table 4-17. Zinc Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. (mg/kg ww)	Lowest Effect Conc. (mg/kg ww)	Body Weight (kg)	Food Ingestion Rate (kg ww/day)	Source
Zinc oxide	rat	**160**	**320**	gestation	reproduction: reduced fetal growth, increased number of resorptions	2,000	4,000	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Schlicker and Cox (1968)
Zinc oxide	ferret	149	433	2 weeks to 6 months	growth: reduced body weight	527	1,527	0.6	0.17	Straube et al. (1980)
Zinc carbonate	rat	400	799	gestation	growth: reduced body weight	5,000	10,000	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Sutton and Nelson (1937)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

bw – body weight

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

ww – wet weight

Bold identifies the NOAEL and LOAEL selected as the TRVs.

4.4.9 Total PAHs

The primary toxic effect of PAH compounds on mammals is the production of tumors in skin and epithelial tissues (Eisler 1987b). The exposure of mammals to carcinogenic PAHs has also resulted in effects on the adrenal and reproductive systems (Eisler 1987b). As the most studied PAH compound and one of the most potent, benzo(a)pyrene is often used as an important representative or surrogate for other PAH compounds (California EPA 1994). Studies on the effects of PAH mixtures on mammals were not identified in the scientific literature, so benzo(a)pyrene was used as a surrogate for total HPAHs. Two studies that evaluated the toxicity of benzo(a)pyrene to mammals were identified for growth, reproduction, and survival endpoints (Table 4-18). Effects were observed in only one of the studies, which exposed mice to 10 mg/kg bw/day, resulting in reduced pup body weights (MacKenzie and Angevine 1981). This dose was selected as the LOAEL TRV. A NOAEL TRV was not available from the study in which the LOAEL of 10 mg/kg bw/day was reported. Because the study was conducted during a sensitive life stage, the NOAEL was estimated using a UF of 5, resulting in a NOAEL TRV of 2.0 mg/kg bw/day.

Table 4-18. Total PAHs Dietary Toxicity Studies for Mammals

PAH Compound	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food IR (kg ww/day)	Source
Benzo(a)pyrene	mouse	nv	**10**[a]	gestation (10 days)	reproduction: reduced pup body weight and testes weight	na	na	na	na	MacKenzie and Angevine (1981)
Benzo(a)pyrene	mouse	33.3	nv	up to 115 days	survival: no effect on survival	250	nv	0.03 (EPA 1993b)	0.004	Neal and Rigdon (1967)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

[a] Exposure was via gavage; the only other available study (Neal and Rigdon 1967) used a dietary exposure, but no effects were observed.

bw – body weight

IR – ingestion rate

LOAEL – lowest-observed-adverse-effect level

na – not applicable

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

UF – uncertainty factor

ww – wet weight

Bold identifies the LOAEL selected as the TRV. A NOAEL TRV was not available from the study in which the LOAEL of 10 mg/kg bw/day was reported. Because the study was conducted during a sensitive life stage, the NOAEL was estimated using a UF of 5. The resulting NOAEL TRV was 2.0 mg/kg bw/day.

4.4.10 Total PCBs

PCBs have been reported to cause a broad range of toxic effects on laboratory mammals under controlled exposure conditions, including mortality, hepatotoxicity, porphyria, body weight loss, dermal toxicity, thymic atrophy, immunosuppressive effects, reproductive and developmental effects, carcinogenesis, and neurotoxicity (Safe 1992, 1991, 1984; Seegal 1996; Safe 1990, 1994; Kimbrough 1985, 1987; Silberhorn et al. 1990; WHO 1993; Bolger 1993; Battershill 1994; Delzell et al. 1994). Review of the toxicology literature indicates that the potency of PCB mixtures depends on the chlorine content of the mixture; and, in general, mixtures with a higher chlorine content (i.e., Aroclors 1242, 1248, 1254, and 1260) are more toxic than mixtures with a lower chlorine content (i.e., Aroclors 1221 and 1232). In general, the gastrointestinal tract of most mammals readily absorbs PCBs, but the absorption rate may be affected by the dose level and lipophilicity of the compound (Eisler 1986; Van den Berg et al. 1998). There is evidence of the placental transfer of PCBs in mammals (Eisler 1986), and PCBs can also accumulate in the lipid portion of milk, resulting in exposure to suckling young.

Adverse reproductive effects (e.g., reduced fertility, litter size, offspring survival) appear to be among the most sensitive *in vivo* endpoints of PCB toxicity in mammals (Golub et al. 1991; Rice and O'Keefe 1995; Hoffman et al. 1996). Reproductive success can be affected directly by toxic action on the differentiated reproductive tract or indirectly on systems that regulate reproduction (e.g., endocrine and central nervous systems). In laboratory studies, PCBs have been reported to elicit a broad range of direct and indirect effects associated with reproductive functions. Direct effects on the gonads and the female reproductive tract have been reported (Fuller and Hobson 1986). The precise mechanism by which PCBs cause reproductive effects on mammals remains unclear, but reproductive success appears to be a sensitive integrated endpoint of *in vivo* toxicity.

Eleven studies that evaluated the toxicity of dietary PCBs to mink were identified (Table 4-19). In the studies reviewed, adverse effects on maternal growth, kit growth, kit survival, whelping success, and reproductive success were reported for captive-bred mink following dietary exposure to PCBs. Reported reproductive effect levels in mink ranged from 0.089 mg/kg bw/day (Brunström et al. 2001) to 2.6 mg/kg bw/day (Bleavins et al. 1980). However, a review of PCB toxicity studies in EPA's ECOTOX database (ECOTOX 2009) indicates that mink are highly sensitive compared with other receptors (e.g., bats, rats, mice, and raccoons). The rat and mouse TRVs presented in Table 4-19 also indicate that rodents are less sensitive to PCBs than are mink. The toxicity of PCBs to shrew is assumed to be more similar to that of other rodents (e.g., mice and rats) than to that of mink. Therefore, the lowest LOAEL based on rodents (1.3 mg/kg bw/day) was selected for the evaluation of risks to shrew.[27] This LOAEL was derived from a mouse study in which offspring survival was reduced (Linzey 1987). A NOAEL of 0.130 mg/kg bw/day was derived from this LOAEL using an uncertainty factor of 10.

[27] No shrew-specific PCB TRVs are available.

Table 4-19. PCB Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet	Lowest Effect Conc. in Diet	Body Weight (kg)	Food IR	Source
Clophen A50	mink	nv	0.089	18 months	reproduction: reduced offspring kit growth	nv	0.1 mg/day	1.12	na	Brunström et al. (2001)
Aroclor 1254	mink	nv	0.13	6 months	reproduction: reduced offspring kit growth rate	nv	1 mg/kg ww	1.34 (Bleavins and Aulerich 1981)	0.18 kg ww/day (Bleavins and Aulerich 1981)	Wren et al. (1987)
Aroclor 1254	mink	nv	0.22	4 and 9 months prior to giving birth	reproduction: reduced number of offspring per female, decrease in offspring kit body weight	nv	2 mg/kg ww	1.34 (Bleavins and Aulerich 1981)	0.15 kg ww/day	Ringer (1983)
Aroclor 1254	mink	0.13	0.26	4 months	reproduction: no kits born alive at 4 weeks	1 mg/kg ww	2 mg/kg ww	1.34 (Bleavins and Aulerich 1981)	0.18 kg ww/day (Bleavins and Aulerich 1981)	Aulerich and Ringer (1977)
Aroclor 1254	mink	nv	0.39	88 to 102 days	reproduction: no kits whelped or born alive	nv	2.5 mg/kg ww	0.87 (Bleavins and Aulerich 1981)	0.13 kg ww/day (Bleavins and Aulerich 1981)	Aulerich et al. (1985)
PCB mixture (composition not reported)	mink	nv	0.51	66 days	reproduction: reduced number of kits born alive	nv	3.3 mg/kg ww	0.87 (Bleavins and Aulerich 1981)	0.13 kg ww/day (Bleavins and Aulerich 1981)	Jensen et al. (1977)
Aroclor 1242	mink	nv	0.65	8 months	reproduction: reduced reproductive success	nv	5 mg/kg ww	1.34 (Bleavins and Aulerich 1981)	0.18 kg ww/day (Bleavins and Aulerich 1981)	Bleavins et al. (1980)
Aroclor 1254	mouse	nv	**1.3**	7.5 to 18 months	reproduction: reduced offspring survival and offspring body weight	nv	10 mg/kg dw	0.0232	0.003 kg dw/day	Linzey (1987, 1988)
Aroclor 1254	mink	nv	1.31	4 weeks	growth: reduced weight gain in adults	nv	10 mg/kg ww	1.34 (Bleavins and Aulerich 1981)	0.18 kg ww/day (Bleavins and Aulerich 1981)	Hornshaw et al. (1986)
Aroclor 1254	mink	nv	1.64	3 months	reproduction: all whelps stillborn	na	na	na	na	Kihlstrom et al. (1992)
Aroclor 1254	mink	1.2	1.8	28 days	growth: reduced female growth	na	na	na	na	Aulerich et al. (1986)
Clophen A50	mink	nv	2.0	3 months	reproduction: all whelps stillborn	na	na	na	na	Kihlstrom et al. (1992)

Table 4-19. PCB Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet	Lowest Effect Conc. in Diet	Body Weight (kg)	Food IR	Source
Aroclor 1254	mink	1.5	2.4	28 days	growth: reduced male and female growth	na	na	na	na	Aulerich et al. (1986)
Aroclor 1016	mink	nv	2.6	8 months	survival/ reproduction: reduced birth weight and growth rate of offspring kits, and 25 % adult female mortality	nv	20 mg/kg ww	1.34 (Bleavins and Aulerich 1981)	0.18 kg ww/day (Bleavins and Aulerich 1981)	Bleavins et al. (1980)
Aroclor 1254	rat	3.7	7.5	10 days during gestation	reproduction: reduced offspring body weight	50 mg/kg dw	100 mg/kg dw	0.241 (NOAEL); 0.259 (LOAEL)	0.018 kg dw/day (NOAEL); 0.0193 kg dw/day (NOAEL)	Spencer (1982)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

bw – body weight

IR – ingestion rate

LOAEL – lowest-observed-adverse-effect level

na – not applicable

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

PCB – polychlorinated biphenyl

UF – uncertainty factor

ww – wet weight

Bold identifies the LOAEL selected as the TRV. A NOAEL TRV was not available from the study in which the LOAEL of 1.3 mg/kg bw/day was reported, so it was estimated using a UF of 10. The resulting NOAEL TRV was 0.13 mg/kg bw/day.

4.4.11 Total DDTs

The exposure of mammals to DDT, DDE, or DDD, particularly during development, may adversely affect the development and function of the reproductive system of both female and male animals (ATSDR 2002). These effects are a result of the binding of DDT and metabolites to receptors for estrogens and androgens and the disruption of actions of natural steroids. Chronic exposure to DDT, DDE, and DDD may also adversely affect the liver and the nervous system of mammals (ATSDR 2002).

Sixteen studies that measured the toxicity of DDT (i.e., technical DDT, a mixture of DDT and its metabolites, or individual DDT, DDE, or DDD isomers) to mammals were identified for growth, reproduction, or survival endpoints (Table 4-20). Reproduction was the most sensitive endpoint in mice and rats exposed to DDT or DDT mixtures. LOAELs ranged from 1.3 mg/kg bw/day for reproduction of mice (Ware and Good 1967) to 113 mg/kg bw/day for growth of hamsters (Rossi et al. 1983). At the lowest LOAEL of 1.3 mg/kg bw/day, litter size was reduced in mice fed a DDT mixture during a critical life stage (gestation) over 120 days (Ware and Good 1967). This dose was selected as the LOAEL TRV. The highest NOAEL below the LOAEL TRV was 1.2 mg/kg bw/day. At this dose, Duby et al. (1971) reported no effects on litter size or weight in rats fed technical DDT over two generations. This NOAEL of 1.2 mg/kg bw/day was selected as the NOAEL TRV.

Table 4-20. Total DDTs Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food IR (kg ww/day)	Source
o,p'-DDT	rat	0.24	nv	two generations	reproduction: reduced litter size and weight	3	nv	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Duby et al. (1971)
p,p'-DDT	mouse	0.6	nv	five generation	survival/reproduction: reduced adult survival, growth, number of pregnancies, number of births, litter size, and pup growth/survival	3.2	nv	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Tarjan and Kemeny (1969)
p,p'- DDT	rat	1.0	nv	two generation	reproduction: reduced litter size and weight	13.3	nv	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Duby et al. (1971)
Technical DDT	rat	**1.2**	nv	two generation	reproduction: reduced litter size and weight	15	nv	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Duby et al. (1971)
DDT[a]	mouse	1.3	nv	120 days	survival: reduced survival	7	nv	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Ware and Good (1967)
DDT[a]	mouse	nv	**1.3**	120 days	reproduction: reduced litter size	nv	7	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Ware and Good (1967)
Technical DDT	rat	1.6	nv	23 months	survival/growth/ reproduction: reduced adult survival, growth, viable litter size, and reproductive lifespan	20	nv	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Ottoboni (1972)
Technical DDT	rat	nv	2.0	7.5 weeks	reproduction: reduced fertility	na	na	na	na	Nickerson and Sniffen (1973)
DDT[a]	rat	0.8	4.0	2 years	reproduction: reduced number of young surviving to weaning (63% vs. 87% lower dose and 88% in control)	10	50	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Fitzhugh (1948)
Technical DDT	rat	6.7	13.4	36 weeks	reproduction: reduced litter size, mating and reproductive success	75	150	0.25	0.022 (EPA 1993b)	Jonsson et al. (1976)
p,p'-DDT	rat	1.6	16	6 months	reproduction: reduced offspring growth	20	200	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Clement and Okey (1974)

Table 4-20. Total DDTs Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food IR (kg ww/day)	Source
DDT[a]	mouse	nv	37	during mating, gestation, and weaning, plus F1 breeding	survival: reduced survival	nv	200	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Cannon and Holcomb (1968)
Technical DDT	mouse	2.4	nv	15 months	survival/reproduction: reduced adult survival, litter size, and litters per pair	17.8	nv	0.015	0.002	Wolfe et al. (1979)
o,p'-DDT	rat	4.0	nv	18 to 23 weeks	reproduction: reduced offspring survival, fertility, fecundity, and growth	40	nv	0.018 (EPA 1993b)	0.18 (EPA 1993b)	Wrenn et al. (1971)
p,p'-DDT and o,p'-DDT	mouse	nv	42	123 weeks	growth: reduced male growth	nv	250	0.040	0.007	Tomatis et al. (1974)
Technical DDT	mouse	9.2	46	six generations	survival/reproduction: reduced lifespan and pup survival	50	250	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Turusov et al. (1973)
Technical DDT	rat	13	nv	37 weeks	survival: reduced survival	150	nv	0.25	0.022 (EPA 1993b)	Jonsson et al. (1976)
Technical DDT (DDD, DDE, DDT)	rat	16	nv	three generations	survival/growth/ reproduction: reduced adult survival, growth, fertility, viability, litter size, and pup survival; increased stillbirths and abnormalities	200	nv	0.35 (EPA 1993b)	0.028 (EPA 1993b)	Ottoboni (1969)
p,p'-DDT	mouse	18	nv	2 years	survival: reduced survival	100	nv	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Thorpe and Walker (1973)
pp'-DDT, -DDD, -DDE	rat	21	nv	6 weeks	survival/growth: reduced survival, body weight (males only)	200	nv	0.16	0.016	Banerjee et al. (1996)
DDT[a]	mouse	55	nv	two generations	growth: reduced body weight	300	nv	0.03 (EPA 1993b)	0.006 (EPA 1993b)	Cannon and Holcomb (1968)
Technical DDT	hamster	113	nv	lifetime	survival: reduced survival	1,000	nv	0.13	0.014	Rossi et al. (1983)

Table 4-20. Total DDTs Dietary Toxicity Studies for Mammals

Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Exposure Duration	Endpoint: Effect	No-Effect Conc. in Diet (mg/kg ww)	Lowest Effect Conc. in Diet (mg/kg ww)	Body Weight (kg)	Food IR (kg ww/day)	Source
Technical DDT	hamster	nv	113	lifetime	growth: reduced body weight	nv	1,000	0.13	0.014	Rossi et al. (1983)

Note: The dose (mg/kg bw/day) was calculated using the reported effect or no-effect concentration, body weight, and food ingestion rate, where dietary-dose TRV (mg/kg bw/day) = (food concentration [mg/kg ww] x FIR [kg/day])/ bw (kg). If the body weight or food ingestion rate were not presented in the study, a citation of the source is provided.

[a] Chemical form was not specified; likely a DDT mixture.

bw – body weight

DDD – dichlorodiphenyldichloroethane

DDE – dichlorodiphenyldichloroethylene

DDT – dichlorodiphenyltrichloroethane

IR – ingestion rate

Bold identifies the LOAEL selected as the TRV.

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

nv – no value (No effects were observed at any dietary concentration [i.e., no LOAEL], or effects were observed at the lowest tissue concentration [i.e., no NOAEL].)

ww – wet weight

4.4.12 Summary of Mammal Dietary TRVs

Table 4-21 summarizes the selected NOAEL and LOAEL TRVs for all mammal dietary COPCs.

Table 4-21. Selected Mammal Dietary TRVs

Refined COPC	Chemical Form	Test Species	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint: Effect	Source
Arsenic	sodium arsenite	rat	2.6	5.4	growth: reduced female body weight	Byron et al. (1967)
Cadmium	cadmium chloride	rat	3.5	13	growth: reduced female body weight	Machemer and Lorke (1981)
Cobalt	cobalt chloride	rat	0.1[a]	1.0	growth: reduced body weight	Chetty et al. (1979)
Copper	copper sulfate	mink	18	26	reproduction: reduced kit survival and litter mass	Aulerich et al. (1982)
Lead	lead acetate	rat	11	90	reproduction: reduced offspring body weight	Azar et al. (1973)
Mercury	methylmercuric chloride	rat	0.0017[b]	0.0084	growth: reduced growth	Verschuuren et al. (1976)
Vanadium	sodium metavanadate	rat	0.27[a]	2.7	growth: reduced body weight	Adachi et al. (2000)
Zinc	zinc oxide	rat	160	320	reproduction: reduced fetal growth and survival	Schlicker and Cox (1968)
Benzo(a) pyrene	benzo(a)pyrene	mouse	2.0[b]	10	reproduction: reduced offspring body weight	MacKenzie and Angevine (1981)
Total PCBs	Aroclor 1254	mouse	0.13[b]	1.3	reproduction: offspring survival and offspring body weight	Linzey (1987, 1988)
Total DDTs	Total DDTs	rat	1.2	1.3	reproduction: reduced litter size and offspring body weight	Duby et al. (1971) (NOAEL); Ware and Good (1967) (LOAEL)

[a] NOAEL was estimated using a UF of 10 (subchronic LOAEL to NOAEL).

[b] NOAEL was estimated using a UF of 5 (chronic LOAEL to NOAEL).

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PCB – polychlorinated biphenyl
TRV – toxicity reference value
UF – uncertainty factor

5.0 RISK CHARACTERIZATION

This section presents the risk characterization for each ROC-refined COPC pair identified in the problem formulation (Section 2.0) and discussed in the exposure and effects assessments (Sections 3.0 and 4.0) of this baseline ERA. HQs were calculated for each ROC-refined COPC pair using the following generic equation:

$$HQ = \frac{EPC}{TRV} \text{ or } HQ = \frac{Diet_{Dose}}{TRV_{Dose}} \qquad \textbf{Equation 5-1}$$

Where:

HQ	unitless	hazard quotient
EPC	mg/kg	media- and COPC-specific exposure point concentration
TRV	mg/kg	media- and COPC-specific toxicity reference value
$Diet_{dose}$	mg/kg bw/day	COPC-specific estimated dietary-dose exposure
TRV_{dose}	mg/kg bw/day	COPC-specific dietary dose-toxicity reference value

In ERAs, HQs greater than 1.0 indicate that the exposure of a receptor is estimated to be greater than a toxicological benchmark for a given COPC. Such a finding is generally regarded as an indication of a potential for adverse effects, particularly if the benchmark is a concentration (or dose) at which adverse effects were observed (i.e., a LOAEL). HQs may also be calculated based on a NOAEL. The potential for adverse effects associated with a NOAEL HQ greater than 1.0 is uncertain because the true threshold for effects occurs at a concentration (or dose) somewhere between the NOAEL and LOAEL. An exposure that falls between the NOAEL and LOAEL may or may not result in an adverse effect. Therefore, both types of HQs are calculated and presented to better describe the potential for adverse effects and to support risk management decisions. Uncertainties inherent in the calculation of HQs, the problem formulation, and the exposure and effects assessments are discussed in the uncertainty analysis. The results of the HQ calculations and the uncertainty analysis are combined in the risk conclusions.

5.1 Invertebrates

This section characterizes risks to aquatic benthic invertebrates and terrestrial invertebrates.

5.1.1 Aquatic Benthic Invertebrate Assessment

Risks to the aquatic benthic invertebrate community were evaluated using two measures of assessment: Force Lake surface sediment concentrations compared with sediment TRVs and Force Lake surface water concentrations compared with water TRVs. Sediment HQs were calculated using Equation 5-1. No refined COPCs were identified for surface water; therefore, no further evaluation of surface water was conducted.

5.1.1.1 Risk Estimates

Risk estimates for the aquatic benthic invertebrate community based on sediment are presented in this section.

Twelve refined COPCs were identified in surface sediment: five metals (cadmium, copper, lead, nickel, and zinc), two individual PAHs (fluoranthene and phenanthrene), total PCBs, and DDTs (as 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, and total DDTs). Surface sediment COPC concentrations from Force Lake were compared to TECs or TELs and PECs or PELs. TECs and TELs are screening thresholds that identify concentrations below which adverse effects are not expected. COPC concentrations greater than PECs or PELs indicate probable effects on sediment-dwelling organisms, although these generic thresholds do not consider site-specific bioavailability.

Table 5-1 presents a summary of refined COPC detection frequencies and concentrations greater than sediment thresholds. All refined COPCs had concentrations that were greater than their respective TECs or TELs. Refined COPC concentrations were greater than TECs or TELs in more than 50% of sediment samples, with HQs ranging from just over 1.0 to 3.8 for all refined COPCs except DDTs (Figure 5-1). The only refined COPCs with PEC or PEL exceedances were 2,4′-DDD, 4,4′-DDD, and 4,4′-DDE; however, total DDT concentrations in all samples were less than the PECs and PELs.

Table 5-1. Risk Estimates for Aquatic Benthic Invertebrates

Refined COPC	Sediment Data		Comparison with TEC or TEL			Comparison with PEC or PEL		
	Range of Detects (µg/kg dw)	Detection Frequency [a]	TEL/TEC (µg/kg dw)	HQ Range	Frequency of Exceedance[b]	PEL/PEC (µg/kg dw)	HQ Range	Frequency of Exceedance[b]
Metals								
Cadmium	2,000 – 2,000	8/11 (73%)	596	**3.4 – 3.4**	8[c]/11 (73%)	3,530	0.57 – 0.57	0/11 (0%)
Copper	16,200 – 72,000	11/11 (100%)	31,600	0.51 **– 2.3**	9/11 (82%)	149,000	0.11 – 0.48	0/11 (0%)
Lead	9,000 – 56,000	11/11 (100%)	35,000	0.26 **– 1.6**	8/11 (73%)	91,300	0.099 – 0.61	0/11 (0%)
Nickel	11,000 – 31,000	11/11 (100%)	18,000	0.61 **– 1.7**	9/11 (82%)	36,000	0.31 – 0.86	0/11 (0%)
Zinc	80,000 – 229,000	11/11 (100%)	121,000	0.66 **– 1.9**	8/11 (73%)	315,000	0.25 – 0.73	0/11 (0%)
PAHs								
Fluoranthene	20 – 190	11/11 (100%)	111	0.18 **– 1.7**	4/11 (36%)	2,230	0.009 – 0.085	0/11 (0%)
Phenanthrene	15 – 120	11/11 (100%)	41.9	0.36 **– 2.9**	7/11 (64%)	515	0.029 – 0.23	0/11 (0%)
PCBs								
Total PCBs	93 – 131	7/11 (64%)	34.1	**2.7 – 3.8**	7[c]/11 (64%)	277	0.34 – 0.47	0/11 (0%)
Pesticides								
2,4'-DDD	8.6 JN – 61 JN	8/11 (73%)	3.54	**2.4 – 17**	8[e]/11 (73%)	8.51	1.0 **– 7.2**	8[f]/11 (73%)
4,4'-DDD	11 J – 47	11/11 (100%)	3.54	**3.1 – 13**	11/11 (100%)	8.51	**1.3 – 5.5**	11/11 (100%)
4,4'-DDE	9.1 – 150	11/11 (100%)	1.42	**6.4 – 110**	11/11 (100%)	6.75	**1.3 – 22**	11/11 (100%)
Total DDTs	22 J – 250	11/11 (100%)	5.28	**4.2 – 47**	11/11 (100%)	572	0.038 – 0.44	0/11 (0%)

[a] Number of detected concentrations/number of surface sediment samples analyzed for the COPC.
[b] Number of detected concentrations greater than sediment threshold/number of surface sediment samples analyzed for the COPC.
[c] One additional sample had an RL greater than the TEL or TEC.
[d] Eight additional samples had RLs greater than the TEL or TEC.
[e] Three additional samples had RLs greater than the TEL or TEC.
[f] Two additional samples had RLs greater than the PEL or PEC.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HQ – hazard quotient
na – not applicable
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probable effect concentration
PEL – probable effect level
TEC – threshold effect concentration
TEL –threshold effect level

Bold identifies HQs > 1.0.

SE-01

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	1.8	0.38
Lead	1.2	0.45
Nickel	1.4	0.69
Zinc	1.5	0.56
Fluoranthene	0.68	0.034
Phenanthrene	1.2	0.095
Total PCBs	3	0.37
2,4'-DDD	12	4.9
4,4'-DDD	7.9	3.3
4,4'-DDE	70	15
Total DDTs	32	0.3

SE-02

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	1.2	0.2
Copper	1.3	0.27
Lead	0.77	0.3
Nickel	1.1	0.53
Zinc	0.98	0.38
Fluoranthene	1.7	0.085
Phenanthrene	2.9	0.23
Total PCBs	0.97	0.12
2,4'-DDD	6.8	2.8
4,4'-DDD	12	4.9
4,4'-DDE	40	8.4
Total DDTs	19	0.17

SE-03

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	2	0.43
Lead	1.5	0.59
Nickel	1.5	0.75
Zinc	1.7	0.66
Fluoranthene	1.7	0.085
Phenanthrene	2.6	0.21
Total PCBs	1.4	0.18
2,4'-DDD	7.1	2.9
4,4'-DDD	12	4.8
4,4'-DDE	65	14
Total DDTs	25	0.23

SE-04

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	2	0.42
Lead	1.3	0.49
Nickel	1.4	0.72
Zinc	1.5	0.59
Fluoranthene	0.43	0.022
Phenanthrene	0.74	0.06
Total PCBs	3.5	0.43
2,4'-DDD	14	5.6
4,4'-DDD	11	4.5
4,4'-DDE	85	18
Total DDTs	40	0.37

SE-05

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	1.8	0.39
Lead	1.3	0.51
Nickel	1.4	0.72
Zinc	1.6	0.6
Fluoranthene	0.58	0.029
Phenanthrene	1.2	0.1
Total PCBs	3.2	0.4
2,4'-DDD	17	7.2
4,4'-DDD	13	5.5
4,4'-DDE	77	16
Total DDTs	42	0.38

SE-06

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	2.3	0.48
Lead	1.6	0.61
Nickel	1.7	0.86
Zinc	1.9	0.73
Fluoranthene	0.88	0.044
Phenanthrene	1.6	0.13
Total PCBs	3.8	0.47
2,4'-DDD	15	6.3
4,4'-DDD	12	4.9
4,4'-DDE	110	22
Total DDTs	47	0.44

SE-07

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	2	0.43
Lead	1.4	0.53
Nickel	1.5	0.75
Zinc	1.6	0.63
Fluoranthene	0.23	0.011
Phenanthrene	0.36	0.029
Total PCBs	3.8	0.47
2,4'-DDD	12	4.9
4,4'-DDD	12	4.9
4,4'-DDE	85	18
Total DDTs	38	0.35

SE-08

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	0.67	0.11
Copper	0.63	0.13
Lead	0.34	0.13
Nickel	0.89	0.44
Zinc	0.66	0.25
Fluoranthene	0.18	0.009
Phenanthrene	0.36	0.029
Total PCBs	0.94	0.12
2,4'-DDD	1.4	0.56
4,4'-DDD	3.1	1.3
4,4'-DDE	7.7	1.6
Total DDTs	4.2	0.038

SE-09

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	1.8	0.38
Lead	1.4	0.53
Nickel	1.4	0.72
Zinc	1.5	0.57
Fluoranthene	1.1	0.054
Phenanthrene	2	0.16
Total PCBs	2.7	0.34
2,4'-DDD	10	4.2
4,4'-DDD	13	5.4
4,4'-DDE	70	15
Total DDTs	34	0.31

SE-10

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	3.4	0.57
Copper	2.2	0.48
Lead	1.6	0.6
Nickel	1.7	0.86
Zinc	1.9	0.72
Fluoranthene	1.1	0.054
Phenanthrene	1.9	0.15
Total PCBs	3.4	0.42
2,4'-DDD	8.2	3.4
4,4'-DDD	12	5.1
4,4'-DDE	99	21
Total DDTs	40	0.37

SE-11

Refined COPC	TEL/TEC HQ	PEL/PEC HQ
Cadmium	0.5	0.085
Copper	0.51	0.11
Lead	0.26	0.099
Nickel	0.61	0.31
Zinc	1	0.38
Fluoranthene	0.28	0.014
Phenanthrene	0.38	0.031
Total PCBs	0.97	0.12
2,4'-DDD	2.4	1
4,4'-DDD	6.5	2.7
4,4'-DDE	6.4	1.3
Total DDTs	7.8	0.072

Figure 5-1. Refined COPC Concentrations in Surface Sediment Samples Relative to Sediment Thresholds for Aquatic Benthic Invertebrates

Risks based on reference areas were estimated to compare Study Area risks relative to reference area risk (Table 5-2). Details regarding reference area concentrations are presented in Attachment 4. Reference area HQs for DDD, DDE, and total DDTs ranged from less than 1.0 to 2.1. Reference area HQs were generally lower than Study Area HQs.

Table 5-2. Comparison of Sediment Reference Area and Study Area Risk Estimates for Aquatic Benthic Invertebrates and DDTs

Refined COPC	Reference Area Concentration or Range (µg/kg dw)[a]	PEC/PEL (µg/kg dw)	HQ	
			Reference Area Range	Study Area Range
2,4′-DDD	6.1 – 6.7	8.51	0.72 – 0.79	1.0 **– 7.2**
4,4'-DDD	6.1 – 6.7	8.51	0.72 – 0.79	**1.3 – 5.5**
4,4'-DDE	7 – 9.8	6.75	1.0 – **1.5**	**1.3 – 22**
Total DDTs	16 – 19	572	0.028 – 0.033	0.038 – 0.44

[a] Details and sources of reference area (urban areas in the vicinity of the Study Area) concentrations are presented in Attachment 4. The range of reference area sediment concentrations for DDTs is based on the range of values from DEQ's Columbia Slough Sediment Project (2005).

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
dw – dry weight
J – estimated concentration
HQ – hazard quotient
N – tentative identification
PEC – probable effect concentration
PEL – probable effect level
RI – remedial investigation
RL – reporting limit

5.1.1.2 Uncertainty Analysis

This section presents uncertainties in the risk characterization for the aquatic benthic invertebrate community. The uncertainties are discussed separately for the problem formulation, exposure assessment, and effects assessment.

Problem Formulation

The primary uncertainties in the problem formulation for aquatic benthic invertebrates are associated with ROC selection and the COPC screen.

ROC Selection

The aquatic benthic invertebrate community as a whole was selected as an ROC because the community encompasses all aquatic benthic invertebrates as a functional group, not as individual species. Because the aquatic benthic invertebrate community is the selected receptor, this approach does not address risks or toxicity to each individual species that could be present in the sediment environment. Instead, the receptor selection addresses effects at the community level, reflecting the diversity of species and ecological functions that are achieved with various aquatic benthic invertebrate assemblages. This receptor group and assessment endpoints (i.e., survival, growth and reproduction) are aimed at protecting community function.

COPC Screen

Forty-eight COIs (or sums) were identified for aquatic benthic invertebrates. Sediment thresholds were not available for 13 of the COIs, including barium, cobalt, vanadium, 2-methylnaphthalene, dibenzofuran, 4 volatile organic compounds (VOCs), and 4 petroleum hydrocarbon mixtures. Risks to aquatic benthic invertebrates from exposure to these COIs could not be evaluated. Water thresholds were available for all four surface water COIs.

Exposure Assessment

Uncertainties in the exposure assessment for aquatic benthic invertebrates were associated with the following factors:

- Depth of the biologically active zone
- Potential contribution of groundwater to exposure
- Potential for soil erosion into Force Lake

These uncertainties are discussed in detail below.

Depth of Biologically Active Zone

Force Lake surface sediment collected from the top 4 inches was used in the evaluation of aquatic benthic invertebrate risks. This depth was selected to represents the biologically active layer, and therefore, represents the potential exposure depth for aquatic benthic invertebrates. Because of shallow depth and small size of Force Lake, little disturbance or mixing to the sediment bottom at Force Lake is expected, and therefore, benthic invertebrates are unlikely to be exposed to sediments at depths greater than 4 inches. Additionally, sampling done during Phase 2 of the RI sampling at Harbor Oil confirmed that concentrations in Force Lake significantly decrease with increasing depths.

Potential Contribution of Groundwater to Exposure

Benthic invertebrates may potentially be exposed to groundwater discharging into Force Lake. Based on the hydrogeology of the Study Area, only shallow groundwater is likely to recharge Force Lake. Therefore, the potential for exposure to groundwater was evaluated in this uncertainty analysis using the shallow groundwater chemistry from four wells located nearest to Force Lake (i.e., MW-1s, MW-2s, GA-33, and A-20). These wells are located on the downgradient (i.e., southern) boundary of the Facility, approximately 150 to 250 ft from Force Lake (see Figure 2-1).

In order to evaluate the potential exposure of aquatic benthic invertebrates to groundwater, groundwater concentrations of all chemicals detected in the four wells were first compared to water thresholds. Acute and chronic water quality criteria were selected for surface water COPCs based on the lower of national water quality criteria protective of freshwater organisms (EPA AWQC) and proposed Oregon water quality criteria (OAR 340-41, Table 33). For those COPCs that had no national or Oregon criteria, Tier II values provided by Suter and Tsao (1996) were used. For pyrene, water criteria were not available from those three sources. Therefore, the water criteria for pyrene was based on the chronic TRV for pyrene reported in EPA (2003). No water thresholds were available for three chemicals: phenol, tert-butyl methyl ether, and diesel range TPH. Potential exposure to these chemicals from groundwater to aquatic benthic invertebrates could not be evaluated. Table 5-3 presents the comparison of detected groundwater concentrations to surface water thresholds, which include AWQC.

Table 5-3. Comparison of Groundwater Concentrations to Surface Water Thresholds

Chemical Detected in Groundwater	Groundwater Concentration Range (µg/L)	Frequency of Detection	Water Threshold (µg/L)	Source	Detected Concentration Greater than Criteria?[a]
Metals					
Aluminum (total)	552 – 5,890	2/2 (100%)	87[b]	EPA AWQC[c]	**yes**
Antimony (total)	0.2 – 0.5	2/8 (20%)	30[b]	Tier II[d]	no
Arsenic (dissolved)	0.8 – 16.6	8/8 (100%)	150[e]	EPA AWQC[c]	no
Barium (total)	65 – 365	10/10 (100%)	4[b]	Tier II[d]	**yes**
Beryllium (total)	1.5	1/2 (50%)	0.66[b]	Tier II[d]	**yes**
Cadmium (dissolved)	< 0.2	0/8 (0%)	0.05[f,g]	EPA AWQC[c]	no
Chromium (dissolved)	< 5	0/8(0%)	74[f]	EPA AWQC[c]	no
Cobalt (total)	3 – 23	6/10 (60%)	23[b]	Tier II[d]	no
Copper (dissolved)	3 – 5	2/8 (25%)	1.33[e,g]	EPA AWQC[c]	**yes**
Lead (dissolved)	< 1	0/8 (0%)	0.18[f,g]	EPA AWQC[c]	no
Manganese (total)	1,360 – 5,790	10/10 (100%)	120[b]	Tier II[d]	**yes**
Mercury (dissolved)	< 0.1	0/8 (0%)	0.77[f]	EPA AWQC[c]	no
Nickel (dissolved)	10 – 20	3/8 (38%)	7.85[e,g]	EPA AWQC[c]	**yes**
Selenium (dissolved)	0.5 – 0.7	4/8 (50%)	5[f]	EPA AWQC[c]	no
Silver (total)	1	1/2 (50%)	3.2[h]	EPA AWQC[c]	no
Thallium (total)	0.015 – 0.0301	2/2 (100%)	12[b]	Tier II[d]	no
Vanadium (total)	4 – 54.4	7/10 (70%)	20[b]	Tier II[d]	**yes**
Zinc (dissolved)	< 10	0/8 (0%)	18.03[f,g]	EPA AWQC[c]	no
PAHs					
2-Methyl-naphthalene	0.14 – 0.24	2/10 (20%)	2.1	Tier II[d]	no
Acenaphthene	0.14 – 3.2	5/10 (50%)	23	Tier II[d]	no
Anthracene	0.15 – 0.18	2/10 (20%)	0.73	Tier II[d]	no
Fluoranthene	0.12 – 0.64	3/10 (30%)	6.16	Tier II[d]	no
Fluorene	0.19 – 1.9	4/10 (40%)	3.9	Tier II[d]	no

Table 5-3. Comparison of Groundwater Concentrations to Surface Water Thresholds

Chemical Detected in Groundwater	Groundwater Concentration Range (µg/L)	Frequency of Detection	Water Threshold (µg/L)	Source	Detected Concentration Greater than Criteria?[a]
Naphthalene	0.10	1/10 (10%)	12	Tier II[d]	no
Phenanthrene	0.16	1/10 (10%)	6.3	Tier II[d]	no
Pyrene	0.12 – 0.53	2/10 (20%)	10.11	EPA (2003)[i]	no
Total HPAHs	0.12 – 1.17	3/10 (30%)	na	na	na
Total LPAHs	0.23 – 5.1	5/10 (50%)	na	na	na
Total PAHs	0.23 – 6.3	5/10 (50%)	na	na	na
Phthalates					
BEHP	0.62 – 1.2	2/2 (100%)	3	Tier II[d]	no
Diethyl phthalate	0.25 J	1/2 (50%)	210	Tier II[d]	no
Di-n-butyl phthalate	0.15 J	1/2 (50%)	35	Tier II[d]	no
Other SVOCs					
1,2-Dichloro-benzene	0.22 J	1/10 (10%)	14	Tier II[d]	no
1,3-Dichloro-benzene	0.2 J	1/10 (10%)	71	Tier II[d]	no
1,4-Dichloro-benzene	1.4	1/10 (10%)	15	Tier II[d]	no
Phenol	0.13 – 0.23 J	2/2 (100%)	na	na	na
Pesticides					
2,4'-DDD	0.0093 J – 0.032	4/8 (50%)	0.001	EPA AWQC[c,j]	**yes**
4,4'-DDD	0.0071 J – 0.24 J	8/10 (80%)	0.001	EPA AWQC[c,j]	**yes**
Total DDTs	0.0071 J – 0.24 J	8/10 (80%)	0.001	EPA AWQC[c,j]	**yes**
VOCs					
Acetone	5.7 – 18	4/10 (40%)	1500	Tier II[d]	no
Chlorobenzene	4.1 – 19.1	3/10 (30%)	64	DEQ (2006)	no
Isopropyl-benzene	0.039 J	1/10 (10%)	7.3	Tier II[d, k]	no
tert-Butyl methyl ether	5.4 – 11	4/10 (40%)	na	na	na
Petroleum					
TPH-diesel range (HCID)	500 – 500	1/2 (50%)	na	na	na

[a] "Yes" indicates that any detected concentration (including the maximum detected concentration) in groundwater was greater than water criteria.

[b] TRV based on total criteria; TRV compared to total concentration.

[c] Chronic EPA AWQC based on EPA (2009a).

[d] Chronic Tier II values based on Suter and Tsao (1996).

[e] TRV based on dissolved criteria; TRV compared to dissolved concentration.

[f] Only the total concentration of this chemical was detected; the TRV is based on dissolved criteria, thus the non-detected result for the filtered sample is presented.

[g] TRV was hardness adjusted based on the average Force Lake hardness (10.7 mg/L $CaCO_3$).

[h] Silver was only analyzed as part of the Ecology and Environment sampling event (2001) in which dissolved metals concentrations were not analyzed. Thus, while the water TRV is based on dissolved concentrations, the total silver concentrations are shown here.

[i] TRV based on PAH mixtures.

[j] TRV based on criterion for 4,4′-DDT.

[k] TRV based on criterion for ethylbenzene.

AWQC – ambient water quality criteria
BEHP – bis(2-ethylhexyl) phthalate
COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
EPA – US Environmental Protection Agency
HCID – hydrocarbon identification
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
J-qualifier– estimated concentration
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
na – not available
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
SVOC – semivolatile organic compound
TPH – total petroleum hydrocarbon
TRV – toxicity reference value
VOC – volatile organic compound
U – concentration was not detected

Forty-four chemicals were detected in shallow groundwater in the four wells nearest Force Lake. Detected shallow groundwater concentrations were greater that water TRVs for seven metals (aluminum, barium, beryllium, copper, manganese, nickel, and vanadium) and DDTs (as 2,4'-DDD, 4,4'-DDD, and total DDTs) (Table 5-3). Chemicals detected in groundwater that had concentrations greater than water TRVs may contribute to toxicity in Force Lake if concentrations in groundwater discharging to the lake are not diminished through natural groundwater attenuation processes during their transport or through dilution with Force Lake water upon discharge. Therefore, chemicals with concentrations that were greater than water TRVs were evaluated further by reviewing the distribution and magnitude of the concentration of these chemicals in Force Lake surface water and sediment. Table 5-4 presents a summary of whether these groundwater chemicals were detected in sediment and surface water.

Table 5-4. Summary of Force Lake Surface Water and Sediment Concentrations for Chemicals with Concentrations Greater than Water TRVs in Groundwater

Chemical	Surface Water		Sediment	
	Detected?	Concentration Range (µg/L)	Detected?	Concentration Range (mg/kg dw)
Metals				
Aluminum	na	na	na	na
Barium	yes	30 – 31[a]	yes	128 – 220
Beryllium	na	na	na	na
Copper	yes	4 – 4[b]	na	na
Manganese	na	na	na	na
Nickel	no	< 10[b]	na	na
Vanadium	no	< 3[a]	yes	32.7 – 74
Pesticides				
2,4'-DDD	no	< 0.01	yes	0.0086 – 0.061
4,4'-DDD	no	< 0.01	yes	0.011 – 0.047
Total DDTs	no	< 0.01	yes	0.022 – 0.250

[a] Metal concentration expressed as total concentration.

[b] Metal concentration expressed as dissolved concentration.

DDD – dichlorodiphenyldichloroethane

DDT – dichlorodiphenyltrichloroethane

dw – dry weight

na – not applicable

RL – reporting limit

TRV – toxicity reference value

One groundwater chemical (copper) was detected in surface water, one metal (vanadium) and DDTs were detected in surface sediment, and one groundwater chemical (barium) was detected in both surface sediment and surface water. Aluminum and beryllium were not analyzed in sediment or surface water.

Sediment concentrations of barium, copper, and vanadium were relatively uniform throughout the lake. Total DDT concentrations were also relatively uniform, with the highest concentrations (>200 µg/kg) in the center or southeastern portion of the lake. Barium and copper were the only groundwater chemicals detected in Force lake surface water; barium surface water concentrations were similar across all three samples and copper was detected in only one sample (SW-01 in the western part of Force Lake near the golf course). Given the uniformity of the concentrations and because the highest concentrations of groundwater chemicals such as DDTs were located on the opposite side of the lake from where shallow groundwater discharges into the lake, groundwater discharging into the lake likely does not represent a significant pathway of exposure for aquatic benthic invertebrates. Furthermore, as discussed during the September 10, 2008, meeting with EPA and detailed in the Voluntary Group response to EPA comments on the preliminary site characterization report (Windward et al. 2008b), DDT migration to Force Lake in shallow groundwater does not appear to be a potentially significant pathway.

Potential for Soil Erosion into Force Lake

Soil particles located near the shoreline of Force Lake have the potential for erosion into the lake, and therefore, aquatic benthic invertebrates in Force Lake may be exposure to eroded soils if they were to migrate to the lake. At the request of EPA, surface soil from eight soil sampling locations located near Force Lake (i.e., WS-15, WS-17, DS-05, WS-20, WS-23, WS-26, WS-28, and WS-31)[28] were compared to PEC/PELs[29] as a worst-case exposure scenario in this uncertainty analysis. In reality, much of the overland surface runoff at the Study Area would be directed through the drainage pathways rather than over the entire wetland bordering the lake.

Seven contaminants that were detected in these soil samples and have a sediment threshold were detected in at least one sample with an HQ greater than 1.0 concentration greater than the PEC or PEL, including: lead, nickel, total PCBs, 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, and total DDTs (Table 5-5).

Table 5-5. Concentrations in Wetland Surface Soil Samples within Approximately 50 ft of Force Lake with Concentrations Greater than Sediment PELs or PECs

Refined COPC	Unit (dw)	PEL/ PEC	Surface Soil Locations with Detected Concentrations Greater than the PEL or PEC		
			Location ID[a]	Range of Soil Concentrations	HQ
Lead	mg/kg	91.3	WS-17, WS-20	102 – 129	1.1 – 1.4
Nickel	mg/kg	36	DS-05, WS-17	38 – 38	1.1
Total PCBs	µg/kg	277	WS-20	1,200	4.3
2,4'-DDD	µg/kg	8.51	DS-05, WS-17, WS-20, WS-23, WS-28, and WS-31	34 – 2,300	4.0 – 270
4,4'-DDD	µg/kg	8.51	DS-05, WS-15, WS-17, WS-20, WS-23, WS-28, and WS-31	18 J – 5,100	2.4 – 600
4,4'-DDE	µg/kg	6.75	DS-05, WS-15, WS-17, WS-20, WS-23, WS-26, WS-28, and WS-31	19 – 540	2.8 – 80
Total DDTs	µg/kg	572	WS-20, WS-23, WS-31	1,180 J – 7,500	2.1 – 13

[a] Data from samples located within approximately 50 ft of Force Lake were considered, including the following samples: DS-05, WS-15, WS-17, WS-20, WS-23, WS-26, WS-28, and WS-31.

DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
HQ – hazard quotient
ID – identification
J-qualifier – estimated concentration
PCB – polychlorinated biphenyl
PEC – probable effect concentration
PEL – probable effect level

[28] These wetland soil samples are located within approximately 50 ft or less of Force Lake.
[29] Sediment TRVs were not available for several chemicals detected in the eight soil sampling locations evaluated, including: antimony, barium, cobalt, vanadium, BEHP, 4-methylphenol, benzoic acid, benzyl alcohol, carbazole, phenol, seven VOCs, and TPHs. These chemicals could not be evaluated.

Lead and nickel concentrations in samples near Force Lake were less than 2 times the PECs or PELs and total PCB concentrations were less than 5 times the PEC or PEL. Dilution of soil particles would likely be far greater than 5 times if soil particles were mobilized during a high flow event and thus the potential for unacceptable risk to the aquatic benthic community is minimal from these contaminants.

DDT concentrations in soil samples ranged from 4.0 to 270 times greater than the PEL for 2,4'-DDD, from 2.4 to 600 times greater than the PEL for 4,4'-DDD, from 2.8 to 80 times greater than the PEL for 4,4'-DDE, and from 2 to 13 times greater than the PEC for total DDT. To further analyze the potential for erosion of soil containing these contaminants, soil concentrations were compared to the nearest lake sediment concentrations:

- **2,4'-DDD:** The two lake sediment locations closest to the wetlands did not have detected concentrations of 2,4'-DDD (RLs were 4.8 and 24 µg/kg dw). These RLs are up to 480 times lower than the wetland soil locations sampled near the shoreline of Force Lake.
- **4,4'-DDD:** The two lake sediment locations closest to the wetlands had detected concentrations of 11 and 42 µg/kg dw. These concentrations are up to 460 times lower than the wetland soil locations sampled near the shoreline of Force Lake.
- **4,4'-DDE:** The two lake sediment locations closest to the wetlands had detected concentrations of 11 and 57 µg/kg dw. These concentrations are up to 49 times lower than the wetland soil locations identified in Table 5-5 as capable of eroding into Force Lake.
- **Total DDTs:** The two lake sediment locations closest to the wetlands had detected concentrations of 22 and 99 µg/kg dw. These concentrations are up to 340 times lower than the wetland soil locations sampled near the shoreline of Force Lake.

Based on the comparison of concentrations in wetland soil and lake sediment, concentrations of 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, and total DDTs are significantly higher in wetland soil than in lake sediment, likely indicating limited transport of wetland soils to Force Lake. Thus, the potential for the exposure of aquatic benthic invertebrates to contaminants in eroding wetland soil is low.

Effects Assessment

The uncertainty in the effects assessment for the aquatic benthic invertebrate community was associated with the selected sediment TRVs. Factors such as site-specific bioavailability, species-specific sensitivities, and exposure to multiple contaminants with potentially synergistic or antagonistic effects contribute to this uncertainty. Uncertainties specific to sediment TRVs (TECs/TELs and PECs/PELs) are presented below.

Effects on the aquatic benthic invertebrate community were assessed by comparing the refined COPC concentrations in surface sediment from Force Lake to the lower of the TEL and the TEC as well as to the lower of the PEL and PEC. TELs identify concentrations below which adverse effects on sediment-dwelling organisms are not expected, but does not necessarily predict toxicity (NOAA 1999). Similarly, TECs provide a basis for predicting the absence of sediment toxicity (MacDonald et al. 2000). Thus, COPCs with concentrations that were greater than TECs and TELs (i.e., with HQs greater than 1.0) may not pose risk to aquatic benthic invertebrates. Concentrations greater than PELs or PECs have a greater likelihood of indicating effects on sediment-dwelling organisms (Smith et al. 1996; MacDonald et al. 2000). Individual DDT isomers (2,4′-DDD, 4,4′-DDD and 4,4′-DDE) exceeded both the selected sediment PELs (8.51 and 6.75 µg/kg dw for DDD and DDE, respectively) as well as the PECs (28 and 31.3 µg/kg dw for DDD and DDE, respectively). However, no sediment sample had sediment concentrations that were greater than the selected sediment PEC (572 µg/kg dw) or the PEL (4,450 µg/kg dw) for total DDTs. In addition, the surface sediment in Force Lake had a generally high TOC content (1.34% to 13.1%, with an average of 7.1%). Because the sediment TRVs are not presented as TOC-normalized concentrations, the decreased bioavailability in Force Lake due to partitioning to TOC is not accounted for and would significantly reduce the potential for effects.

5.1.1.3 Risk Conclusions

Risks to aquatic benthic invertebrates were evaluated using two measures of assessment: surface sediment and surface water chemistry. No refined COPCs were identified for surface water. The potential for exposure of aquatic benthic invertebrates to groundwater and soils that could erode into Force Lake was also evaluated. The following are risk conclusions for aquatic benthic invertebrates based on the risk estimates and uncertainty analysis:

- Twelve refined COPCs were identified for sediment: five metals (cadmium, copper, lead, nickel, and zinc), two individual PAHs (fluoranthene and phenanthrene), total PCBs, and DDTs (as 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, and total DDTs).
- Refined COPC concentrations were greater than the TEC and TEL thresholds in some of the samples; however, because TELs and TECs identify concentrations below which adverse effects on sediment-dwelling organisms are not expected, exceedances of TECs and TELs do not necessarily predict toxicity. Risks to aquatic benthic invertebrates are therefore likely to be low[30] for metals, individual PAHs, total PCBs, and total DDTs because sediment concentrations were less than PEC and PEL thresholds.
- The concentrations of individual DDT metabolites (2,4'-DDD, 4,4'-DDD, 4,4'-DDE) were greater than PECs and PELs. However, total DDT concentrations in sediment were less than the PEC, and the TOC content of the sediment was relatively high (ranging from 1.34% to 13.1%, with an average of 7.1%), limiting bioavailability. Therefore, the risks from DDTs to aquatic benthic invertebrates

[30] Low risk for benthic invertebrates is defined as PEL/PEC HQ is < 1.0, but TEL/TEC HQ is > 1.0.

may be overestimated. Reference area HQs for DDTs ranged from less than 1.0 to 2.1.

- Shallow groundwater from the south end of the Facility is not expected to be a significant pathway of exposure to aquatic benthic invertebrates.
- The potential for unacceptable risk to aquatic benthic invertebrates from potential erosion of wetland soils into the lake is minimal because: 1) metals and PCB concentrations in wetland soils near Force Lake were low compared with PECs and PELs, and 2) total DDT concentrations in lake sediment were much lower than in wetland soils, likely indicating limited transport of wetland soils to Force Lake.

5.1.2 Terrestrial Invertebrate Assessment

Risks to the terrestrial invertebrate community were evaluated using one measure of assessment: wetland soil concentrations compared to soil TRVs. This section presents the risk estimates, uncertainty analysis, and risk conclusions for the terrestrial invertebrate community.

5.1.2.1 Risk Estimates

Five soil refined COPCs were identified: chromium, copper, mercury, zinc, and total PAHs. Table 5-6 presents a summary of HQs for all soil refined COPCs relative to generic soil screening values, referred to as soil TRVs. All samples analyzed for chromium were greater than the soil TRVs. Zinc concentrations were greater than soil TRVs in more than half of the samples in which these COPCs were analyzed. Two samples had total HPAH concentrations that were greater than the soil TRV and 27 samples had copper concentrations greater than the soil TRV. No samples exceeded the soil TRV for mercury.

Table 5-6. Risk Estimates for Terrestrial Invertebrates

Refined COPC	Soil Data		Comparison with Soil TRVs		
	Range of Detects (mg/kg dw)	Detection Frequency[a]	Soil TRV (mg/kg dw)	HQ Range	Detection of Exceedance[b]
Metals					
Chromium	6.6 – 149	71/71 (100%)	2.0	**3.3 – 75**	71/71 (100%)
Copper	10.3 – 1,240 J	71/71 (100%)	50	0.21 – **25**	27/71 (38%)
Mercury	0.04 J – 0.4	64/71 (90%)	0.5	0.08 to 0.8	0/71 (0%)
Zinc	37 – 748	71/71 (100%)	120	0.31 – **6.2**	49/71 (69%)
PAHs					
Total HPAHs	0.101 J - 57	70/71 (99%)	18	0.0056 – **3.2**	2/71 (3%)

a Number of detected concentrations/number of soil samples analyzed for the COPC.

b Number of detected concentrations greater than soil TRV/number of soil samples analyzed for the COPC.

COPC – contaminant of potential concern
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
TRV – toxicity reference value
Bold identifies HQs > 1.0.

Risks based on background or reference areas were estimated to compare Study Area risks relative to background or reference area risks for those refined COPCs with HQs greater than 1.0 (Table 5-7). Details and sources of background and reference area concentrations are presented in Attachment 4. The background HQ for chromium (21) was within the range of Study Area HQs for chromium (3.3 to 75). Only 18% of the soil samples (13/71) had concentrations that exceeded the background soil chromium concentration of 42 mg/kg dw. The concentrations in these samples ranged from 44 to 149 mg/kg dw. Background or reference area HQs were all less than 1.0 for copper, zinc, and total HPAHs.

Table 5-7. Comparison of Background or Reference Area and Study Area Risk Estimates for Terrestrial Invertebrates

Refined COPC	Background or Reference Area Concentration or Range[a] (mg/kg dw)	Soil TRV	HQ	
			Background or Reference Area	Study Area
Metals				
Chromium	42	2	**21**	**3.3 – 75**
Copper	36	50	0.72	0.21 – **25**
Zinc	86	120	0.72	0.31 – **6.2**
PAHs				
Total HPAHs	0.054 – 0.388 3	18	0.003 – 0.022	0.0056 – **3.2**

[a] Details and sources of soil background and reference area (urban areas in the vicinity of the Study Area) concentrations are presented in Attachment 4. Background soil concentrations for chromium, copper, mercury, and zinc are based on DEQ's Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Soil Background Concentrations for Metals (DEQ 2002). The range of soil reference area concentrations for HPAHs is based on the range of concentrations reported in DEQ's Columbia Slough Sediment Project (2005).

COPC – contaminant of potential concern
DEQ – Oregon Department of Environmental Quality
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
PAH – polycyclic aromatic hydrocarbon
TRV – toxicity reference value

During wetland soil sampling, information regarding the presence of earthworms and other terrestrial invertebrates was noted for 41 of the wetland surface sampling locations (including two soil samples from the wetland ditch).[31] Earthworms and/or other terrestrial invertebrates (i.e., sowbugs and snails) were observed at 30 of these 41 locations (in 73% of samples). These locations included locations with exceedances of soil TRVs (Table 5-8), including one sample (WS-39) for which HQs were greater than 1.0 for chromium, copper, zinc, and total HPAHs. There was no relationship between the magnitude of HQs and the presence (or absence) of earthworms or other terrestrial invertebrates.

[31] Information regarding the presence of earthworms or other invertebrates was not available for six soil sampling locations where subsurface soil was collected (i.e., DS-02, DS-03, DS-05, WS-06, WS-19, and WS-26), at nine soil berm locations (i.e., SB-01 through SB 09), or for historical data (soil sampling locations WL01 through WL05).

Table 5-8. Summary of Locations Where the Presence or Absence of Earthworms Was Noted

Sampling Location[a]	Depth (in.)	Refined COPC HQ				Were Earthworms Observed?
		Chromium	Copper	Zinc	Total HPAHs	
DS-01	0 – 6	**278**	**3.0**	**6.0**	0.20	yes
DS-04	0 – 6	**150**	**2.4**	**5.1**	0.088	yes
WS-01	0 – 6	**72**	0.97	**1.1**	0.027	yes
WS-02	0 – 6	**64**	0.99	**1.1**	0.029	yes
WS-03	0 – 6	**67**	0.76	0.94	0.029	yes
WS-04	0 – 6	**82**	0.99	**2.4**	0.030	yes
WS-05	0 – 6	**82**	**1.0**	**1.4**	0.032	yes
WS-07	0 – 6	**190**	**2.1**	**1.3**	0.12	yes
WS-08	0 – 6	**95**	0.89	**1.4**	0.029	yes
WS-09	0 – 6	**50**	0.82	**1.3**	0.018	yes
WS-10	0 – 6	**41**	0.57	0.73	0.025	yes
WS-11	0 – 6	**373**	**2.9**	**3.5**	0.13	no[b]
	6 – 12	**137**	**1.5**	**2.1**	0.028	
WS-12	0 – 6	**91**	0.81	**1.4**	0.037	no
WS-13	0 – 6	**72**	0.66	0.82	0.015	yes
WS-14	0 – 6	**73**	**1.2**	**1.8**	0.041	yes
WS-15	0 – 6	**55**	0.57	0.87	0.022	no[b]
WS-16	0 – 6	**68**	**1.1**	**1.3**	0.076	yes
WS-17	0 – 6	**150**	**1.4**	**2.1**	0.049	no
WS-18	0 – 6	**63**	0.74	0.92	0.052	no
WS-20	0 – 6	**103**	**2.4**	**2.0**	0.25	no
	6 – 12	**180**	**1.9**	**2.0**	0.031	
WS-21	0 – 6	**22**	0.63	0.93	0.36	yes
	6 – 12	**32**	0.44	**1.2**	0.15	
WS-22	0 – 6	**30**	0.90	0.83	0.067	no[d]
WS-23	0 – 6	**35**	**1.2**	**1.8**	0.091	yes
WS-24	0 – 6	**50**	0.62	0.93	0.037	no
WS-25	0 – 6	**51**	**1.2**	**2.6**	0.19	yes
	6 – 12	**62**	**1.1**	**2.3**	0.11	
WS-27	0 – 6	**35**	**1.4**	**1.8**	0.037	yes
WS-28	0 – 6	**45**	0.66	**1.2**	0.048	no
WS-29	0 – 6	**29**	0.57	**1.3**	0.33	no
WS-30	0 – 6	**51**	0.92	0.93	0.033	no
WS-31	0 – 6	**48**	0.96	**1.7**	0.038	no
WS-32	0 – 6	**43**	0.81	**1.4**	0.037	no
WS-33	0 – 6	**50**	0.69	**1.1**	0.034	yes
WS-34	0 – 6	**17**	0.21	0.31	0.028	yes
WS-35	0 – 6	**66**	0.99	**1.1**	0.032	yes
WS-36	0 – 6	**83**	**1.0**	**1.1**	0.024	yes
WS-37	0 – 6	**91**	0.85	**1.3**	0.022	yes
WS-38	0 – 6	**105**	**2.3**	**3.0**	0.087	no
WS-39	0 – 6	**103**	**3.2**	**3.4**	**1.3**	yes
WS-40	0 – 6	**47**	0.97	**2.1**	0.14	yes
WS-41	0 – 6	**43**	0.77	**1.5**	0.10	yes

Table 5-8. Summary of Locations Where the Presence or Absence of Earthworms Was Noted

Sampling Location[a]	Depth (in.)	Refined COPC HQ				Were Earthworms Observed?
		Chromium	Copper	Zinc	Total HPAHs	
WS-42	0 – 6	**50**	0.57	0.73	0.017	yes

[a] Includes all sampling locations with information available regarding the presence of earthworms or other invertebrates. Information was not available for six soil sampling locations where subsurface soil was collected (i.e., DS-02, DS-03, DS-05, WS-06, WS-19, and WS-26), at nine soil berm locations (i.e., SB-01 through SB 09), or for historical data (soil sampling locations WL01 through WL05).

[b] Earthworms were not observed at this location, but snails were observed.

[c] HQ is based on a non-detected value.

[d] Earthworms were not observed at this location, but a sowbug was observed.

COPC – contaminant of potential concern

HPAH – high-molecular-weight polycyclic aromatic hydrocarbon

HQ – hazard quotient

Bold identifies HQs greater than 1.0.

Although soil concentrations were greater than soil TRVs for these refined COPCs, earthworms were frequently observed during field sampling, including in those areas where metals concentrations were highest. Soil TRVs for all refined COPCs (i.e., copper, chromium, mercury, zinc, and HPAHs) are based on adverse effects to earthworm (e.g., mortality).

5.1.2.2 Uncertainty Analysis

This section presents uncertainties in the risk characterization for the terrestrial invertebrate community. The uncertainties are discussed separately for the problem formulation, exposure assessment, and effects assessment.

Problem Formulation

The primary uncertainties in the problem formulation for terrestrial invertebrates are associated with ROC selection and the COPC screen.

ROC Selection

The terrestrial invertebrate community as a whole was selected as an ROC because the community encompasses all terrestrial invertebrates as a functional group, not as individual species. Because the terrestrial invertebrate community is the selected receptor, this approach does not address risks or toxicity to each individual species that could be present in the wetland soil environment. Instead, the receptor selection addresses effects at the community level, reflecting the diversity of species and ecological functions that are achieved with various terrestrial invertebrate assemblages. This receptor group, assessment endpoints (survival, growth and reproduction) are aimed at protecting community function.

COPC Screen

Eighty-eight chemicals (or chemical sums) were identified as COIs for terrestrial invertebrates. Soil thresholds were not available for 48 of the COIs, including vanadium, 4 PCB mixtures, 6 DDTs isomers and total

DDTs, delta-BCH, methoxychlor, 2 PAHs (2-methylnaphthalene and dibenzofuran), 10 SVOCs, 16 VOCs, and 6 petroleum hydrocarbon mixtures. Risks to terrestrial invertebrates from exposure to these COIs could not be evaluated.

Exposure Assessment

The primary uncertainty in the exposure assessment for terrestrial invertebrates was associated with the depth of the biologically active zone. Wetland soil used in the evaluation of terrestrial invertebrates include surface soil (0 to 6 inches) from 52 locations, and soil collected from an intermediate depth (6 to 12 inches) from 10 locations, and an intermediate depth (6 to 24 inches) from 9 soil berm locations. Terrestrial invertebrates may be exposed to refined COPCs at the intermediate soil depth less frequently than the surface depth; however, refined COPC concentrations at intermediate depths were generally lower than concentrations in surface soil samples at the same location. Thus, the inclusion of intermediate soil depths generally does not affect the number of sampling locations with concentrations greater than the soil TRV. In addition, the exclusion of intermediate soil samples would still result in TRV exceedances for all of the refined COPCs identified. Table 5-9 identifies the number of surface and intermediate soil samples with TRV exceedances.

Table 5-9. Identification of Shallow and Intermediate Wetland Soil Samples with TRV Exceedances

Refined COPC	No. of Samples Exceeding Soil TRV		
	Total[a]	Surface Soil	Intermediate Soil
Metals			
Chromium	71/71	52/52	19/19
Copper	27/71	20/52	7/19
Mercury	0/71	0/52	0/19
Zinc	49/71	39/52	10/19
PAHs			
Total HPAHs	2/71	1/52	1/19

[a] Number of detected concentrations greater than soil TRV/number of soil samples analyzed for the COPC.

COPC – contaminant of potential concern

HPAH – high-molecular-weight polycyclic aromatic hydrocarbon

PAH – polycyclic aromatic hydrocarbon

TRV – toxicity reference value

Effects Assessment

There is high uncertainty in the effects assessment because the soil TRVs are conservative screening levels, which are not necessarily associated with effects for relevant terrestrial invertebrate species and do not take into account site-specific bioavailability or mixtures of contaminants. Metals are less mobile in soil than in aquatic systems (Smolders et al. 2007), and the criteria for metals in soil are generally conservative because they are based on worst-case assumptions about metals speciation and bioavailability (Allen 2002). The bioavailability (and therefore the toxicity) of metals in soil to terrestrial invertebrates is dependent on site-specific soil chemistry factors, including pH, organic matter, clay content, and weathering and aging processes (Gorsuch et al. 2006).

The source of each of the TRVs and the relevance of the TRV to estimating risks to terrestrial invertebrates is summarized below:

- Soil TRVs for chromium, copper, and mercury were based on DEQ (2001) screening values from the earthworm thresholds reported by Efroymson et al. (1997). Thresholds from Efroymson et al. (1997) are based on a compilation of toxicity studies from the literature. Thresholds for earthworms are expected to be protective of terrestrial invertebrates, Efroymson et al. (1997) states that site-specific considerations, including background, should be evaluated in addition to the comparison of soil concentrations to these thresholds to assess the potential for effects. Additional information regarding these TRVs is presented below:
    - **Chromium:** A soil TRV of 0.4 was reported in Efroymson et al. (1997) based on the use of a safety factor of 5 applied to the 2 mg/kg dw LOEC, which was associated with a 75% reduction in earthworm survival following exposure to chromium (VI) as potassium dichromate. Chromium (III) is more common in soil, and therefore, application of a screening value based on exposure to chromium (VI), which is more toxic than chromium III, is highly conservative. In addition, according to Efroymson et al. (1997), confidence in the 2 mg/kg dw benchmark is low because it is based on only five reported concentrations causing toxicity to earthworms.
    - **Copper:** The benchmark for Cu was established at 50 mg/kg dw based on toxicity to earthworms from multiple studies in which worms were exposed to various forms of copper. Confidence in this benchmark is moderate (Efroymson et al. 1997).
    - **Mercury:** A soil TRV of 0.1 was reported in Efroymson et al. (1997) based on the use of a safety factor of 5 applied to the 0.5 mg/kg dw LOEC, which was associated with a 65% reduction in earthworm survival following exposure to mercury as mercury chloride. Confidence in this benchmark is low because of the limited amount of data (Efroymson et al. 1997).

- The soil thresholds for zinc, and total HPAHs are based on EPA's soil screening levels for invertebrates. Ecological soil screening levels are based on a compilation of toxicity studies from the literature. Ecological SSLs may be overly conservative for evaluating risks to terrestrial invertebrates because ecological SSLs are derived to avoid underestimating risk (EPA 2007b). Additional information regarding the TRVs for zinc and HPAHs is presented below:
  - **Zinc:** Six studies were identified as eligible for ecological SSL derivation for zinc. The ecological SSL is the geometric mean of the maximum allowable toxicant concentration (MATC) and the effects concentration of 10% of the organisms (EC10) for at least three test species under different test conditions (pH and percent organic matter) and is equal to 120 mg/kg dw.
  - **HPAHs:** Six studies were identified as eligible for ecological SSL derivation for PAHs. The ecological SSL is the geometric mean of the MATC and EC10 values for four test species under different test conditions (pH and percent organic matter) and is equal to 18 mg/kg dw.

Because all of the selected soil TRVs are intended to be used as generic screening thresholds, risk estimates for terrestrial invertebrates are highly uncertain because site-specific bioavailability is not considered.

There is also uncertainty associated with the effects assessment because risk from some chemicals could not be evaluated because soil thresholds were not available from the sources specified in the risk assessment scoping memorandum (Windward and Bridgewater 2008): EPA's SSLs (2007b) for invertebrates, ORNL invertebrate soil thresholds (Efroymson et al. 1997), or Oregon DEQ soil screening level values for terrestrial invertebrates (2001). Two of these chemicals that could not be evaluated for terrestrial invertebrates were total DDTs and total PCBs.

5.1.2.3 Risk Conclusions

Risks to terrestrial invertebrates were evaluated using one measure of assessment: wetland soil chemistry. The following are risk conclusions for terrestrial invertebrates based on the risk estimates and uncertainty analysis:

- Five COPCs were identified in soil: four metals (chromium, copper, mercury, and zinc), and total HPAHs.
- Chromium, copper, and zinc may pose risks to terrestrial invertebrates because soil concentrations of these COPCs are greater than soil TRVs in at least half of all wetland samples; however, risk estimates are likely overestimates due to the conservative nature of the soil TRVs, which do not account for site-specific bioavailability. Mercury HQs were less than 1.0 in all soil samples, indicating negligible risks because soil concentrations are less than the soil TRV. The background HQ for

chromium was within the range of Study Area HQs for chromium. Only 18% of the soil samples (13/71) exceeded the background soil chromium concentration of 42 mg/kg dw. The concentrations in these samples ranged from 44 to 149 mg/kg dw.

- Only two wetland soil sample locations had HPAH concentrations that were greater than the conservative soil TRV (one sample near the western corner of the Facility and one sample between the Facility and Force Lake). Thus, the potential impacts to the terrestrial invertebrate community are highly localized and not widespread.

5.2 Fish

For fish, three measures of assessment were evaluated for the two fish ROCs, pumpkinseed and brown bullhead:

- For the tissue-residue assessment, HQs were calculated for both brown bullhead and pumpkinseed using Equation 5-1, wherein EPCs were compared to tissue-residue TRVs. HQs were calculated using both NOAEL and LOAEL TRVs.
- For the dietary-dose assessment, risks were also estimated using an HQ approach, as defined in Equation 5-1, wherein dietary doses (ingestion of prey and incidental ingestion of sediment) were compared to relevant TRVs. Both NOAEL and LOAEL TRVs were used to estimate risks.
- For the surface water evaluation, no refined COPCs were identified, and therefore, no further evaluation of surface water was conducted.

The following subsections present the risk estimates, uncertainties, and risk conclusions for the two fish ROCs.

5.2.1 Pumpkinseed

This section presents risk estimates, uncertainties, and risk conclusions for pumpkinseed.

5.2.1.1 Risk Estimates

One refined tissue-residue COPC (total PCBs) was evaluated for pumpkinseed. Two refined COPCs were evaluated for pumpkinseed using the dietary-dose approach: cadmium and copper. No refined COPCs were identified in surface water. Table 5-10 presents the calculated NOAEL- and LOAEL-based HQs for these refined COPCs.

Table 5-10. Risk Estimates for Pumpkinseed

Refined COPC	Unit	EPC or Diet$_{dose}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Tissue Residue						
Total PCBs	µg/kg ww	280	104	520	**2.7**	0.54
Dietary Dose						
Cadmium	mg/kg bw/day	0.15	3.2	4.6	0.047	0.033
Copper	mg/kg bw/day	3.5	1	2	**3.5**	**1.8**

bw – body weight
COPC – contaminant of potential concern
EPC – exposure point concentration
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PCB – polychlorinated biphenyl
TRV – toxicity reference value
ww – wet weight
Bold HQs are greater than 1.0.

The NOAEL-based HQ for total PCBs using the tissue-residue approach was 2.7, but the LOAEL-based HQ was less than 1.0, indicating risks to pumpkinseed from PCBs are low.[32]

NOAEL-based HQs were less than 1.0 for cadmium in the diet, and thus, risk from cadmium is negligible.[33] NOAEL- and LOAEL-based HQs were greater than 1.0 for copper; NOAEL- and LOAEL-based HQs were 3.5 and 1.8, respectively, indicating a higher potential for adverse effects for these three COPCs.

Dietary risks based on regional background were estimated to compare Study Area risks relative to background risk for copper (Table 5-11). Background concentrations are presented in Attachment 4. The background LOAEL-based HQ for copper was less than 1.0 (0.3).

Table 5-11. Comparison of Background and Study Area HQs for Pumpkinseed

Refined COPC	Unit	Background Dose$_{diet}$	LOAEL TRV	LOAEL-Based HQ	
				Background	Study Area
Copper	mg/kg bw/day	0.59	2	0.30	**1.8**

a Details and sources of background concentrations are presented in Attachment 4. Background sediment concentration for copper (12 mg/kg dw) is based on DEQ's Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002).

bw – body weight
COPC – contaminant of potential concern
DEQ – Oregon Department of Environmental Quality
dw – dry weight
LOAEL – lowest-observed-adverse-effect level
HQ – hazard quotient
TRV – toxicity reference value
Bold HQs are greater than 1.0.

[32] Low risk is defined as NOAEL HQ is > 1.0, but LOAEL HQ is < 1.0.
[33] Negligible risk is defined as NOAEL HQ is ≤ 1.0.

5.2.1.2 Uncertainty Analysis

This section presents a discussion of uncertainties associated with the problem formulation and the exposure and effects assessments for pumpkinseed.

Problem Formulation

The primary uncertainties in the problem formulation for pumpkinseed are associated with ROC selection and the COPC screen.

ROC Selection

Pumpkinseed were selected as a fish ROC and is representative of invertebrate-consuming fish that may be present at Force Lake. Mosquitofish were identified as a fish ROC in the RI/FS Work Plan (Bridgewater et al. 2008b) and risk assessment scoping memorandum (Windward and Bridgewater 2008) instead of pumpkinseed. However, it was determined that pumpkinseed are a more appropriate ROC for this ERA both because mosquitofish were not observed during the April 2009 survey and because mosquitofish are no longer released by the Multnomah County Vector Control to help manage mosquito populations.[34] Pumpkinseed are protective of both water column feeding and benthic feeding invertivorous fish because their diet was modeled assuming 100% ingestion of aquatic benthic invertebrates. Aquatic benthic invertebrates are expected to have a higher concentration than water-column invertebrates because of their direct contact with chemicals in sediment.

COPC Screen

Thirty-three metals and PAHs (as individuals and sums) were identified as dietary fish COIs. Effects data for fish were not available for five of the COIs, including barium, cobalt, nickel, 2-methylnaphthalene, and dibenzofuran. Risks to fish from exposure to these COIs could not be evaluated. Sixteen tissue COIs (as individuals and sums) were identified as fish tissue COIs. No tissue TRVs were available for the following tissue COIs: acetone, carbon disulfide, methyl ethyl ketone, toluene, and 4 TPH mixtures. Risks to fish from exposure to these COIs could not be evaluated. Water thresholds were available for all four surface water COIs.

Exposure Assessment

Uncertainties in the exposure assessment for pumpkinseed were associated with the following factors:

- Use of BSAFs to estimate tissue concentrations
- COPC bioavailability
- Dietary composition
- Incidental sediment ingestion rate
- Potential contribution of groundwater to exposure

[34] Information provided to Doug Cramer (PGE) by the Multnomah County Vector Control.

The uncertainties associated the potential of groundwater to exposure were discussed in Section 5.1.1.2. The conclusions of that analysis (minimal potential for unacceptable effects) pertain to fish as well. The remaining uncertainties are discussed in detail below.

Selected BSAFs

BSAFs were used to estimate total PCB tissue-residue concentrations for pumpkinseed as well as pumpkinseed invertebrate prey tissue concentrations. Attachment 2 presents the details and assumptions used to select BSAFs from the literature. The following general uncertainties are associated with the use of BSAFs:

- BSAFs from the literature are highly variable, likely because BSAFs presented in the literature are based on various species, various exposure conditions and food webs, and various concentration ranges. For this ERA, average BSAFs were calculated from databases or reported in the literature; it is unknown whether average BSAFs across multiple species over or underestimate tissue concentrations in Force Lake. COPC-specific BSAF variability information is presented below.
    - **Total PCBs:** The total PCB fish BSAF (6.45) was based on the average BSAF reported in EPA's BSAF database (EPA 2008). Total PCBs BSAFs in EPA's BSAF database were highly variable, ranging from 0.0038 to 258. The median BSAF was 2.1.
    - **Cadmium:** The invertebrate BSAF of 3.438 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 88 BSAFs compiled from multiple sources, ranging from 0.049 to 41.55. The median BSAF was 0.614.
    - **Copper:** The invertebrate BSAF of 2.14 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 74 BSAFs compiled from multiple sources, ranging from 0.032 to 16.63. The median BSAF was1.647.
- Most BSAFs express the relationship between sediment and tissue as a ratio, which assumes that the relationship is linear; however, the relationship between sediment and tissue COPC concentrations may be better expressed as a non-linear regression. In addition, the level of regulation (of certain metals) and metabolism (of PAHs) can affect the uptake of chemicals in more complicated ways that are not captured through the use of a single number.
- The details of the methods used to derive BSAFs in the various literature and databases are generally not presented. Considerations, such as the spatial scale over which tissue and sediment samples were analyzed, have a large influence on BSAFs.

COPC Bioavailability

Metals may be less bioavailable in ingested sediment than in ingested prey. In calculating the ingested doses, it was assumed that metals were 100% bioavailable, which may overestimate risk if the primary source of the dose is sediment. No more than 1% percent of the pumpkinseed ingested dose for cadmium and copper is from sediment exposure, therefore, the bioavailability of these metals is not expected to significantly change risk estimates and would not change risk conclusions.

Dietary Composition

Pumpkinseed were assumed to ingest 100% aquatic invertebrates. However, the calculated pumpkinseed prey concentrations were based on 100% ingestion of aquatic benthic invertebrates using BSAFs and sediment concentrations. These estimated tissue concentrations may be overestimated because pumpkinseed generally feeds on both water-column and aquatic benthic invertebrates, and aquatic benthic invertebrates are likely to have higher exposure than water-column invertebrates.

Incidental Sediment Ingestion Rate

Ingested doses of refined COPCs were estimated using a SIR of 1%. Increasing the SIR to 10% would increase HQs by no more than 16% and would not change risk conclusions (i.e., NOAEL- and LOAEL-based HQs would still be greater than 1.0 for copper and less than 1.0 for cadmium).

Effects Assessment

Uncertainty associated with available toxicity benchmarks for fish may affect risk estimates. General uncertainties with selected tissue and dietary TRVs are as follows:

- None of the laboratory toxicological studies used to derive TRVs were conducted using ROC species.
- The laboratory studies on which TRVs are based were conducted in controlled settings using single-chemical exposures. Effects associated with multiple-chemical exposure and other environmental stressors present at the site (e.g., habitat loss) were not factored into these studies. It is unknown if these factors would result in additive, synergistic, antagonistic, or neutral effects on overall risk conclusions.
- NOAELs were not available for some COPCs, so they were estimated from LOAELs using uncertainty factors. Uncertainty factors may over or underestimate risks based on NOAELs.
- Tissue-residue TRVs for PCBs were based only on studies reporting whole-body tissue TRVs. However, PCB TRVs were also available based on egg tissue concentrations. Effect concentrations reported in eggs and embryos ranged from 857 to 77,900 µg/kg ww in the four studies (Fisher et al. 1994; Hendricks et al. 1981; McCarthy et al. 2003; Freeman and Idler 1975) The estimated pumpkinseed PCB tissue concentration was

280 µg/kg ww, which is much lower than the range of tissue concentrations reported in eggs.

In addition, some of the selected TRVs are considered less certain than others if endpoints were subchronic or if data quality was questionable. A summary of the uncertainties for the fish TRVs for all COPCs evaluated is presented in Table 5-12.

Table 5-12. Uncertainty Associated with Selected Tissue and Dietary TRVs for Fish

Refined COPC	No. of TRV Studies	Uncertainty in and Selection of TRV
Tissue		
Total PCBs	21	Selected TRVs were based on lowest LOAEL reported in reviewed literature based on reproduction endpoint (fecundity); however, effect was not dose-responsive and tissue concentrations in experimental fish with reduced fecundity in the first spawning season were not measured in the second spawning season, when experimental fish did spawn; the number of fish exposed at each treatment level and evaluated for effects was unclear; NOAEL extrapolated from LOAEL based on uncertainty factor of 5.
Diet		
Cadmium	9	Selected TRVs were based on a reproduction endpoint.
Copper	13	Selected TRVs were based on a growth endpoint.

COPC – contaminant of potential concern

LOAEL – lowest-observed-adverse-effect level

NOAEL – no-observed-adverse-effect level

PCB – polychlorinated biphenyl

TRV – toxicity reference value

5.2.1.3 Risk Conclusions

Risks to pumpkinseed were evaluated using three measures of assessment: evaluation of estimated tissue-residue, estimated dietary doses, and surface water chemistry data. The potential for exposure of fish to groundwater and soils that could erode into Force Lake was also evaluated; however, it was determined that shallow groundwater from the south end of the Facility is not expected to be a significant pathway of exposure to aquatic ROCs (see Section 5.1.1.2), including fish.

One refined COPC was identified for tissue (total PCBs), and two refined COPCs were identified in the pumpkinseed diet (cadmium and copper). No refined COPCs were identified for surface water. Uncertainties in the problem formulation and the effects and exposure assessments for pumpkinseed were evaluated to arrive at the following risk conclusions for each refined COPC:

- **Cadmium:** Risks from cadmium were negligible because both NOAEL- and LOAEL-based HQs were less than 1.0.

- **Copper:** The LOAEL-based HQ for copper was 1.8, just over the threshold of 1.0, which is indicative of the potential for adverse effects. The background LOAEL-based HQ for copper was less than 1.0.
- **Total PCBs:** Risk from total PCBs is low because the NOAEL-based HQ was greater than 1.0 but the LOAEL-based HQ was less than 1.0.

In summary, copper was the only refined COPC that had a dietary LOAEL-based HQs greater than 1.0 (1.8). Key uncertainties that may affect the pumpkinseed risk estimates include the use of variable literature-based BSAFs (effect on risk estimates is unknown) and the selected dietary composition for pumpkinseed (risks may be overestimated based on assumption of aquatic benthic invertebrates prey).

5.2.2 Brown Bullhead

This section presents risk estimates, uncertainties, and risk conclusions for brown bullhead.

5.2.2.1 Risk Estimates

One tissue-residue refined COPC (total PCBs) was evaluated for pumpkinseed. Two refined COPCs were evaluated for pumpkinseed using the dietary-dose approach: cadmium and copper. No refined COPCs were identified for surface water. Table 5-13 presents the calculated NOAEL- and LOAEL-based HQs for these refined COPCs.

Table 5-13. Risk Estimates for Brown Bullhead

Refined COPC	Unit	EPC/ $Diet_{dose}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Tissue Residue						
Total PCBs	µg/kg ww	230	104	520	**2.2**	0.44
Dietary Dose						
Cadmium	mg/kg bw/day	0.089	3.2	4.6	0.028	0.019
Copper	mg/kg bw/day	2.1	1	2	**2.1**	**1.1**

bw – body weight
COPC – contaminant of potential concern
EPC – exposure point concentration
HQ – hazard quotient
Bold HQs are greater than 1.0.
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
TRV – toxicity reference value
ww – wet weight

The NOAEL-based HQ for total PCBs using the tissue-residue approach was 2.2, but the LOAEL-based HQ was less than 1.0, indicating risks to brown bullhead from PCBs are low.

NOAEL-based HQs were less than 1.0 for cadmium, and thus, risk from cadmium is negligible. NOAEL- and LOAEL-based HQs were greater than 1.0 for copper; NOAEL- and LOAEL-based HQs were 1.1 and 2.1, respectively, indicating a potential for adverse effects.

Dietary risks based on regional background were estimated to compare Study Area risks relative to background risk for copper (Table 5-14). Background concentrations are presented in Attachment 4. The background LOAEL-based HQ for copper was less than 1.0 (0.18).

Table 5-14. Comparison of Background and Study Area HQs for Brown Bullhead

Refined COPC	Unit	Background $Dose_{diet}$	LOAEL TRV	LOAEL-Based HQ	
				Background	Study Area
Copper	mg/kg bw/day	0.36	2	0.18	**1.1**

[a] Details and sources of background concentrations are presented in Attachment 4. The background sediment concentration for copper (12 mg/kg dw) was based on DEQ's Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002).

bw – body weight

COPC – contaminant of potential concern

DEQ – Oregon Department of Environmental Quality

dw – dry weight

Bold HQs are greater than 1.0.

LOAEL – lowest-observed-adverse-effect level

HQ – hazard quotient

TRV – toxicity reference value

5.2.2.2 Uncertainty Analysis

This section presents a discussion of uncertainties associated with the problem formulation and the exposure and effects assessments for brown bullhead.

Problem Formulation

The primary uncertainties in the problem formulation for brown bullhead are associated with ROC selection and the COPC screen. The uncertainty associated with the COPC screen for fish is presented in Section 5.2.1.2. Brown bullhead were selected to be protective of fish in Force Lake that may consume both invertebrates and fish. The brown bullhead is the only fish identified in Force Lake (Table 2-1) that feeds on fish. Brown bullhead are assumed to be protective of carp in this ERA because the brown bullhead and carp diets are similar, in which the majority of the diet is comprised of insects.

Exposure Assessment

Uncertainties in the exposure assessment for brown bullhead were associated with the following factors:

- Use of BSAFs to estimate tissue concentrations
- COPC bioavailability
- Dietary composition
- Incidental sediment ingestion rate

- Potential contribution of groundwater to exposure

The uncertainties associated with the potential contribution of groundwater to exposure were discussed in Section 5.1.1.2. The remaining uncertainties are discussed in detail below.

Selected BSAFs

BSAFs were used to estimate total PCB tissue-residue concentrations for brown bullhead as well as brown bullhead invertebrate prey tissue concentrations. Attachment 2 presents the details and assumptions used to select BSAFs from the literature. Section 5.2.1.2 presents the general uncertainties associated with BSAFs and the variability of the total PCB BSAF for fish and cadmium, copper, and vanadium invertebrate BSAFs. The variability of the remaining BSAFs used to estimate the concentration in fish ingested by brown bullhead is presented below:

- **Cadmium:** The invertebrate BSAF of 3.438 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 88 BSAFs that were compiled from multiple sources and ranged from 0.049 to 41.55. The median BSAF was 0.614.
- **Copper:** The invertebrate BSAF of 2.14 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 74 BSAFs that were compiled from multiple sources and ranged from 0.032 to 16.63. The median BSAF was1.647.

COPC Bioavailability

Metals may be less bioavailable in ingested sediment than in ingested prey. In calculating the ingested doses, it was assumed that metals were 100% bioavailable, which may overestimate risk if the primary source of the dose is sediment. Less than 10% percent[35] of the brown bullhead ingested dose of cadmium and copper is from sediment exposure, and thus this uncertainty is not expected to significantly affect risk conclusions.

Dietary Composition

Brown bullhead were assumed to ingest 90% aquatic invertebrates and 10% fish. HQs for all COPCs would decrease if a higher portion of the brown bullhead diet was based on fish prey, but LOAEL-based HQs for cadmium would still be less than 1.0 even if 100% fish were ingested. LOAEL-based HQs for copper would be less than 1.0 if fish made up 100% of the diet, but would be greater than 1.0 if fish made up at least 50% of the diet. While ingestion of a higher portion of fish would change risk conclusions for copper and brown bullhead, the literature (FishBase 2007; EPA 2002b) indicates that fish are not a predominant prey item of the brown bullhead.

Incidental Sediment Ingestion Rate

Ingested doses of refined COPCs for brown bullhead were estimated using a SIR of 10%. Increasing the SIR to 20% would increase HQs by less than 9% and would not change risk conclusions (NOAEL- and

[35] The contribution of sediment concentrations to exposure dose for cadmium and copper are 3% and 5%, respectively

LOAEL-based HQs would still be greater than 1.0 for copper and less than 1.0 for cadmium).

Effects Assessment

Uncertainties associated with available tissue and dietary toxicity benchmarks for fish are discussed in Section 5.2.1.2. The estimated brown bullhead tissue concentration 230 µg/kg ww was also lower than the egg tissue PCB TRVs discussed in Section 5.2.1.2.

5.2.2.3 Risk Conclusions

Risks to brown bullhead were evaluated using three measures of assessment: evaluation of estimated tissue-residue, estimated dietary doses, and surface water chemistry data. The potential for exposure of fish to groundwater and soils that could erode into Force Lake was also evaluated; however, it was determined that shallow groundwater from the south end of the Facility is not expected to be a significant pathway of exposure to aquatic ROCs, including fish.

One refined COPC was identified for tissue (total PCBs), two refined COPCs were identified for the pumpkinseed diet (cadmium and copper). No refined COPCs were identified for surface water. Uncertainties in the problem formulation, the effects and exposure assessments, and risk characterization for pumpkinseed were evaluated to arrive at the following risk conclusions for each COPC:

- **Cadmium:** Risks from cadmium were negligible because both NOAEL- and LOAEL-based HQs were less than 1.0.
- **Copper:** The LOAEL-based HQ for copper was 1.1, just over the threshold of 1.0, which is indicative of the potential for adverse effects. The background HQ for copper was less than 1.0.
- **Total PCBs:** Risk from total PCBs was low because the NOAEL-based HQ was greater than 1.0, but the LOAEL-based HQ was less than 1.0.

In summary, copper was the only refined COPC that had a LOAEL-based HQ greater than 1.0 (1.1). Key uncertainties that may affect the risk estimates include the use of variable literature-based BSAFs (effect on risk estimates is unknown).

5.3 Birds and Mammals

Risks were estimated using an HQ approach, as defined in Equation 5-1, wherein the ingestion dose of prey and incidental ingestion of sediment was divided by the applicable TRV. Both NOAEL and LOAEL TRVs were used to calculate risks.

This section presents a risk characterization and uncertainty analysis for each of the five wildlife ROCs. The assessment for each ROC estimates risk by calculating HQs using estimated ingested doses of COPCs, as described in Section 3.3, and TRVs, as presented in Sections 4.3 (bird

TRVs) and Section 4.4 (mammal TRVs). Background or reference area risk estimates were also calculated to compare to Study Area risks for those refined COPCs where LOAEL-based HQs were greater than 1.0. Uncertainties in the exposure and effects data that may result in overestimates or underestimates of risk for each of the refined COPCs are discussed. Risk conclusions are presented for each ROC; these conclusions integrate risk estimates with associated uncertainties.

5.3.1 Ruddy Duck

This section present risk characterization, uncertainties, and risk conclusions for ruddy duck.

5.3.1.1 Risk Estimates

Two refined COPCs were evaluated for ruddy duck: mercury and total DDTs. Table 5-15 presents the calculated NOAEL- and LOAEL-based HQs for these COPCs.

Table 5-15. Risk Estimates for Ruddy Duck

Refined COPC	Unit	$Dose_{diet}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Mercury	mg/kg bw/day	0.019	0.018	0.091	**1.1**	0.21
Total DDTs	µg/kg bw/day	58	64	320	0.91	0.18

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
TRV – toxicity reference value
Bold HQs are greater than 1.0.

Both NOAEL- and LOAEL-based HQs were less than 1.0 for total DDTs, indicating negligible risk to ruddy duck. For mercury, the NOAEL-based HQ was greater than 1.0 and the LOAEL-based HQ was less than 1.0, indicating low risk. No comparisons of risks were made based on background because no refined COPCs exceeded LOAEL-based TRVs.

5.3.1.2 Uncertainty Analysis

This section presents a discussion of uncertainties associated with the problem formulation and the exposure and effects assessments for ruddy duck.

Problem Formulation

The primary uncertainties in the problem formulation for ruddy duck are associated with ROC selection and the COPC screen.

ROC Selection

There is some uncertainty associated with how well the ruddy duck represents other aquatic invertivorous birds that use Force Lake. Force Lake represents key breeding habitat for ruddy duck, and thus, the ruddy duck is expected to use Force Lake habitat at least as frequently as other invertivorous ducks. The ruddy duck is also expected to be protective of other dabbling ducks that are primarily herbivorous because COPC concentrations in ruddy duck prey are expected to be higher than concentrations in plants, especially for bioaccumulative contaminants.

COPC Screen

Forty-eight chemicals (or chemical sums) were identified as COIs for aquatic ROCs, including ruddy duck. Effects data for birds were not available for ten of the COIs, including barium, three VOCs, two PAHs (2-methylnaphthalene and dibenzofuran) and 4 petroleum hydrocarbon mixtures. Risks to aquatic birds from exposure to these COIs could not be evaluated.

Exposure Assessment

Uncertainties in the exposure assessment for ruddy duck were associated with the following factors:

- Use of BSAFs to estimate prey concentrations
- COPC bioavailability
- Dietary composition
- Study Area use
- Incidental sediment ingestion rate

These uncertainties are discussed in detail below.

Selected BSAFs

BSAFs were used to estimate invertebrate prey tissue concentrations for ruddy duck. Attachment 2 presents the details and assumptions used to select BSAFs from the literature. Section 5.2.1.2 presents the general uncertainties associated with BSAFs. The variability associated with each of the BSAFs used to estimate ruddy duck dietary doses for each of the COPCs is summarized below:

- **Mercury:** The invertebrate BSAF of 1.204 was based on the non-depurated mean BSAF reported by ORNL (1998). This value was based on 13 BSAFs compiled from multiple sources, ranging from 0.286 to 2.868. The median BSAF was 1.081.
- **Total DDTs:** The total DDT BSAF (5.21) was based on the weighted average BSAF of the three DDT metabolites detected in sediment: 2,4′-DDD, 4,4′-DDD, and 4,4′-DDE. BSAFs for DDT metabolites (4.32 for 2,4′-DDD and 4,4′-DDD and 5.94 for 4,4′-DDE) were based on EPA’s BSAF database (EPA 2008). DDT metabolite BSAFs in EPA’s BSAF database ranged from 0.034 to 49. The median BSAFs for 4,4′-DDD and 4,4′-DDE were 0.62 and 2.9, respectively.

COPC Bioavailability

Metals may be less bioavailable in ingested sediment than in ingested prey. In calculating the ingested doses, it was assumed that metals were 100% bioavailable, which may overestimate risk if the primary source of the dose is sediment. Eight percent of the ruddy duck ingested dose for mercury was from sediment exposure, therefore, HQs may somewhat overestimate risks. However, these small changes in HQs are unlikely to change risk conclusions.

Dietary Composition

Ruddy duck were assumed to ingest 100% aquatic invertebrates, although their diet is also comprised of plant material. Risks may be overestimated to ruddy ducks, especially for bioaccumulative COPCs (i.e., mercury and total DDTs) because lower trophic level prey (aquatic plants) would be expected to have lower contaminant concentrations.

Study Area Use

Ruddy duck HQs were estimated assuming an SUF of 1.0 because Force Lake represents key breeding habitat for this ROC. However, ruddy duck are migratory species, and therefore, an SUF of 0.5 was also evaluated to estimate HQs if ruddy duck were present for only half of the year (Table 5-16). While HQs were lower assuming an SUF of 0.5, risk conclusions were unaffected, except for mercury (the NOAEL-based HQ was 1.1 with an SUF of 1.0).

Table 5-16. HQ Calculations for Ruddy Duck Based on an SUF of 0.5

Refined COPC	Unit	$Dose_{diet}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Mercury	mg/kg bw/day	0.0095	0.018	0.091	0.53	0.10
Total DDTs	µg/kg bw/day	29	64	320	0.45	0.091

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
Bold HQs are greater than 1.0.
NOAEL – no-observed-adverse-effect level
SUF – site use factor
TRV – toxicity reference value

Incidental Sediment Ingestion Rate

Ingested doses of refined COPCs for ruddy duck were conservatively estimated using a SIR of 10%. Increasing the SIR to 20% would increase HQs by no more than 0.2. Therefore, risk conclusions would not change based on changing the SIR.

Effects Assessment

Uncertainty associated with available toxicity benchmarks for birds may affect risk estimates. General uncertainties with selected bird and mammal TRVs are as follows:

- None of the laboratory toxicological studies used to derive TRVs were conducted using ROC species.
- The laboratory studies on which TRVs are based were conducted in controlled settings using single-chemical exposures. Effects associated with multiple-chemical exposure and other environmental stressors present at the site (e.g., habitat loss) were not factored into these studies. It is unknown if these factors would result in additive, synergistic, antagonistic, or neutral effects on overall risk conclusions.

- NOAELs were not available for mercury or total DDTs, so they were estimated from LOAELs.

In addition, TRVs are considered less certain if there were a small number of studies, if endpoints were subchronic, or if data quality was questionable. A summary of the uncertainties for the bird TRVs for all COPCs evaluated are presented in Table 5-17.

Table 5-17. Uncertainty Associated with Selected TRVs for Birds

Refined COPC[a]	No. of TRV Studies	Uncertainty in and Selection of TRV
Mercury	8	selected TRVs were based on a chronic growth endpoint; NOAEL extrapolated from LOAEL based on uncertainty factor of 5
Total DDTs	9[b]	selected TRVs were based on eggshell thinning, eggshell breakage, and nestling mortality; NOAEL extrapolated from LOAEL based on uncertainty factor of 5

[a] Refined COPC for any bird receptor (i.e., ruddy duck, great blue heron, or red-tailed hawk).

[b] Additional TRV studies were available; only the TRV studies reporting the lowest LOAEL TRVs (<1 mg/kg bw/day) were presented in Section 4.3.2.

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
TRV – toxicity reference value

5.3.1.3 Risk Conclusions

Risks to ruddy duck were evaluated by comparing estimated dietary doses to dietary TRVs. Two refined COPCs were identified: total DDTs and mercury. Uncertainties in the problem formulation, the effects and exposure assessments, and risk characterization for ruddy duck were evaluated to arrive at the following risk conclusions:

- **Total DDTs:** Risks from total DDTs are negligible because both NOAEL- and LOAEL-based HQs were less than 1.0.
- **Mercury:** The NOAEL-based HQ for mercury was just over 1.0, but the LOAEL-based HQ was less than 1.0, indicating low risk from mercury.

In summary, none of the COPCs for ruddy duck had LOAEL-based HQs greater than 1.0. Key uncertainties that may affect the risk estimates include the use of variable literature-based BSAFs (effect on risk estimates is unknown).

5.3.2 Great Blue Heron

This section present risk characterization, uncertainties, and risk conclusions for great blue heron.

5.3.2.1 Risk Estimates

One refined COPC (total DDTs) was evaluated for great blue heron. Both NOAEL- and LOAEL-based HQs were less than 1.0 for total DDTs, indicating negligible risk to great blue heron (Table 5-18). No comparisons of risks were made based on background because no refined COPCs exceeded LOAEL-based TRVs.

Table 5-18. Risk Estimates for Great Blue Heron

COPC	Unit	$\text{Dose}_{\text{diet}}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Total DDTs	µg/kg bw/day	53	64	320	0.83	0.17

bw – body weight
COPC – contaminant of potential concern
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
TRV – toxicity reference value
Bold HQs are greater than 1.0

5.3.2.2 Uncertainties

This section presents a discussion of uncertainties associated with the problem formulation and the exposure and effects assessments for great blue heron.

Problem Formulation

Primary uncertainties in the problem formulation for great blue heron are associated with ROC selection and the COPC screen. Uncertainties in the COPC screen for birds were discussed in Section 5.3.1.2. Great blue heron were selected as the most appropriate piscivorous bird ROC because of the heron rookery located near Force Lake and the observation of heron at the Study Area. The great blue heron is expected to be protective of other piscivorous birds, such as osprey, because of the higher frequency of feeding at Force Lake from the nearby heron rookery.

Exposure Assessment

Uncertainties in the exposure assessment for great blue heron were associated with the following factors:

- Use of BSAFs to estimate prey concentrations
- Study Area use
- Incidental sediment ingestion rate

These uncertainties are discussed in detail below.

Selected BSAFs

BSAFs were used to estimate fish prey tissue concentrations for great blue heron. Attachment 2 presents the details and assumptions used to select BSAFs from the literature. Section 5.2.1.2 presented the general uncertainties associated with BSAFs. The variability associated with each of the BSAFs used to estimate great blue heron dietary doses for the single refined COPC evaluated is summarized below:

- **Total DDTs:** The total DDT BSAFs for invertebrates and fish (5.21 and 3.0, respectively) were based on the weighted average BSAFs of the three DDT metabolites detected in sediment: 2,4,-DDD, 4,4-DDD, and 4,4'-DDE. BSAFs for DDT metabolites were based on EPA's BSAF database (EPA 2008). Invertebrate DDT metabolite BSAFs in EPA's BSAF database ranged from 0.034 to 49. Fish DDT metabolite BSAFs in EPA's BSAF database ranged from 0.070 to 108.

Study Area Use

Great blue heron HQs were estimated assuming an SUF of 1.0 because the rookery is near Force Lake. However, there are other nearby aquatic habitats where heron could forage, and therefore, HQs were also calculated using an SUF of 0.5. However, reducing the site use assumption would not change the risk conclusions (i.e., the NOAEL- and LOAEL-based HQs would still be less than 1.0 for total DDT).

Incidental Sediment Ingestion Rate

Ingested doses of refined COPCs for great blue heron were conservatively estimated using a SIR of 2%. Increasing the SIR to 10% would increase HQs by no more than 0.2. Therefore, risk conclusions would not change based on changing the SIR.

Effects Assessment

Uncertainties associated with available toxicity benchmarks for birds were discussed in Section 5.3.1.2.

5.3.2.3 Risk Conclusions

Risks to great blue heron were evaluated by comparing estimated dietary doses to dietary TRVs for one refined COPC (total DDTs). Risks from total DDTs were negligible because both NOAEL- and LOAEL-based HQs were less than 1.0.

5.3.3 Red-Tailed Hawk

This section presents risk characterization, uncertainties, and risk conclusions for red-tailed hawk.

5.3.3.1 Risk Estimates

One refined COPC was evaluated for red-tailed hawk: total DDTs. Table 5-19 presents the calculated NOAEL- and LOAEL-based HQs for this COPC.

Table 5-19. Risk Estimates for Red-Tailed Hawk

COPC	Unit	$Dose_{diet}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Total DDTs	µg/kg bw/day	370	64	320	**5.8**	**1.2**

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
HQ – hazard quotient
Bold HQs are greater than 1.0.
LOAEL – lowest-observed-adverse-effect level
na – not applicable; no TRV available
NOAEL – no-observed-adverse-effect level
TRV – toxicity reference value

The total DDT NOAEL- and LOAEL-based HQs were 5.8 and 1.2, respectively, indicating a potential for adverse effects.

Dietary risks based on regional reference areas were estimated to compare to Study Area risks for total DDT (Table 5-20). A range of reference area concentrations was identified for total DDTs; no specific background concentration for total DDTs has been established. Reference area concentrations are presented in Attachment 4. Reference area HQs for total DDTs were less than 1.0.

Table 5-20. Comparison of Reference Area and Study Area HQs for Red-Tailed Hawk

COPC	Unit	Background $Dose_{diet}$[a]	LOAEL TRV	LOAEL-Based HQ	
				Reference Area	Study Area
Total DDTs	mg/kg bw/day	6.5 – 150	320	0.020 – 0.47	**1.2**

[a] Details and sources of reference area (urban areas in the vicinity of the Study Area) concentrations are presented in Attachment 4. The range of reference area soil concentrations for DDTs (15 to 355 µg/L dw) are based on the range of sediment values from the Radio Tower Site (URS 2000).

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
Bold HQs are greater than1.0.
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
RI – remedial investigation
TRV – toxicity reference value

5.3.3.2 Uncertainties

This section presents a discussion of uncertainties associated with the problem formulation and the exposure and effects assessments for red-tailed hawk.

Problem Formulation

The primary uncertainties in the problem formulation for red-tailed hawk are associated with ROC selection and the COPC screen.

ROC Selection

There is some uncertainty associated with the selection of red-tailed hawk to conservatively represent other terrestrial birds that utilize the wetlands associated with the Harbor Oil Study Area. Red-tailed hawk are expected to have a higher exposure than terrestrial birds that feed lower on the food chain (e.g., robin), especially for bioaccumulative chemicals, such as DDTs.

COPC Screen

Eighty-eight chemicals (or chemical sums) were identified as COIs for terrestrial ROCs, including red-tailed hawk. Effects data for birds were not available for 37 of the COIs, including antimony, barium, beryllium, manganese, silver, 2 PAHs, 9 SVOCs, 15 VOCs, and 6 petroleum hydrocarbon mixtures. Risks to terrestrial birds from exposure to these COIs could not be evaluated.

Exposure Assessment

Uncertainties in the exposure assessment for red-tailed hawk were associated with the following factors:

- Use of BAFs
- Dietary composition
- Study Area use
- Incidental soil ingestion rate
- Inclusion of wetland soil from the intermediate sampling depth

These uncertainties are discussed in detail below.

Selected BAFs

BAFs were used to estimate small mammal prey tissue concentrations for red-tailed hawk. Attachment 2 presents the details and assumptions used to select BAFs from the literature. The general uncertainties associated with BAFs are the same general uncertainties for BSAFs presented in Section 5.2.1.2. The variability associated with each of the BAFs used to estimate red-tailed hawk dietary doses for the single COPC evaluated is summarized below:

- **Total DDTs:** Mammal tissue concentrations were estimated based on the mammal prey to mammal tissue update factor of 4.83 reported in EPA (2007a) and the following equation:

$$C_{mammal} = (C_{plant} \times 0.75) + (C_{inver} \times 0.25) \times 4.83 \qquad \textbf{Equation 5-2}$$

Where:

C_{mammal}	mg/kg dw	COPC concentration in mammal tissue
C_{plant}	mg/kg dw	COPC concentration in plants
$C_{inverts}$	mg/kg dw	COPC concentration in invertebrates

The mammal tissue concentration was calculated assuming 75% plant-eating mammals and 25% invertebrate-eating mammals based on literature that indicates that the red-tailed hawk small mammal diet consists primarily of plant-eating mammals (Csuti et al. 2001; EPA 1993b; Marshall et al. 2003). The variability of the total DDT BAF is dependent on the type of prey the mammal consumes. A higher proportion of invertebrate-eating mammals in the red-tailed hawk diet would result in a higher mammal tissue concentration in the red-tailed hawk prey.

Dietary Composition

Red-tailed hawk were assumed to ingest 100% small mammals; however, hawk may also ingest a small portion of birds, amphibians, and reptiles. BAFs were not available for estimating tissue concentrations in bird, reptile, or amphibian prey and thus risks to red-tailed hawk may be under or overestimated. However, because hawk primarily feed on small mammals, risk estimates would not be expected to change significantly.

Study Area Use

Red-tailed hawk HQs were estimated assuming an SUF of 0.1 because of their large home range. Red-tailed hawk home ranges can be quite large, ranging up to 1,500 hectares (EPA 1993b). The wetland area sampled covers an area of approximately 1.8 hectares, so it was conservatively estimated that the wetland area sampled represents 10% of the hawk foraging area, although site use may actually be less than 1% based on the range reported in the literature. HQs would be less than 1.0 if an SUF of 0.01 was assumed. HQs would be greater than 1.0 if an SUF of 1.0 was used (i.e., NOAEL- and LOAEL-based HQs would be 58 and 12, respectively, for total DDTs). However, an SUF of 1.0 for a wide-ranging species like red-tailed hawk is very unlikely.

Incidental Soil Ingestion Rate

To address uncertainties in the amount of soil incidentally ingested by red-tailed hawk while foraging, ingested doses of refined COPCs were calculated assuming the SIR was 10% of the FIR versus 1% assumed. This conservative assumption would result in an increase of HQs by less than 0.1 and thus would not change risk conclusions.

Inclusion of Wetland Soil Data from the Intermediate Sampling Depth

Wetland soil used in the evaluation of terrestrial ecological ROCs, including the red-tailed hawk included surface soil (0 to 6 inches) from 52 locations, soil collected from an intermediate depth (6 to 12 inches) from 10 locations, and an intermediate depth (6 to 24 inches) from 9 soil berm locations. Red-tailed hawk may be exposed to chemicals at the intermediate soil depth less frequently than the surface depth. Table 5-21 presents a comparison of wetland soil EPCs used in the ERA based on UCLs including all surface and intermediate soil data and soil UCLs based only surface soil data. Using only surface samples would not change risk conclusions for red-tailed hawk (NOAEL and LOAEL HQs would still be greater than 1.0 for total DDTs).

Table 5-21. Comparison of UCLs Based on Surface and Intermediate Wetland Soil Samples and Surface Wetland Soil Samples Only

Refined COPC[a]	Unit	Surface and Intermediate Soil Data		Surface Only Soil Data	
		Count	UCL[b]	Count	UCL
Metals					
Arsenic	mg/kg dw	71	9.3	52	11
Cadmium	mg/kg dw	71	1	52	1.2
Cobalt	mg/kg dw	71	12	52	12
Copper	mg/kg dw	71	150	52	83
Lead	mg/kg dw	71	78	52	110

Table 5-21. Comparison of UCLs Based on Surface and Intermediate Wetland Soil Samples and Surface Wetland Soil Samples Only

Refined COPC[a]	Unit	Surface and Intermediate Soil Data		Surface Only Soil Data	
		Count	UCL[b]	Count	UCL
Mercury	mg/kg dw	71	0.16	52	0.21
Vanadium	mg/kg dw	71	74	52	74
Zinc	mg/kg dw	71	240	52	330
PAHs					
Total PAHs	µg/kg dw	71	8,300	52	6,300
PCBs					
Total PCBs	µg/kg dw	71	680	52	830
Pesticides					
Total DDTs	µg/kg dw	71	8,500	52	10,000

a Refined COPC for any terrestrial receptor (i.e., red-tailed hawk, Eastern cottontail, and shrew).

b These data represented the EPC_{soil} in the dietary-dose calculations.

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
ERA – ecological risk assessment
na – not applicable
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
UCL – upper confidence limit on the mean

Effects Assessment

Uncertainties associated with available toxicity benchmarks for birds were discussed in Section 5.3.1.2.

5.3.3.3 Risk Conclusions

Risks to red-tailed hawk were evaluated by comparing estimated dietary doses to dietary TRVs. One refined COPC was identified: total DDTs. Uncertainties in the problem formulation, the effects and exposure assessments, and risk characterization were evaluated to arrive at the following risk conclusions:

- **Total DDTs:** The LOAEL-based HQ for total DDTs was greater than 1.0 (1.2), indicating the potential for adverse effects. Reference area LOAEL-based HQs were less than 1.0.

Key uncertainties in the red-tailed hawk assessment included the BAFs used to estimate COPC concentrations in prey and the medium uncertainty in the selected TRVs.

5.3.4 Eastern Cottontail

This section present risk characterization, uncertainties, and risk conclusions for Eastern cottontail.

5.3.4.1 Risk Estimates

Five COPCs were evaluated for Eastern cottontail: cobalt, copper, mercury, vanadium, and total PAHs. Table 5-22 presents the calculated NOAEL- and LOAEL-based HQs for these refined COPCs.

Table 5-22. Risk Estimates for Eastern Cottontail

Refined COPC	Unit	$Dose_{diet}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Cobalt	mg/kg bw/day	0.035	0.1	1	0.35	0.035
Copper	mg/kg bw/day	2.6	18	26	0.14	0.10
Mercury	mg/kg bw/day	0.010	0.0017	0.0084	**5.9**	**1.2**
Vanadium	mg/kg bw/day	0.21	0.27	2.7	0.78	0.078
Total PAHs	μg/kg bw/day	2,200	2,000	10,000	**1.1**	0.22

bw – body weight
COPC – contaminant of potential concern
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
TRV – toxicity reference value
Bold HQs are greater than 1.0.

NOAEL- and LOAEL-based HQs were less than 1.0 for cobalt and copper, indicating negligible risk. The NOAEL-based HQ was greater than 1.0 for total PAHs, but the LOAEL-based HQ was less than 1.0, indicating low risk. Both the NOAEL- and LOAEL-based HQs were greater than 1.0 for mercury; NOAEL- and LOAEL-based HQs were 5.9 and 1.2, respectively, indicating a potential for adverse effects.

Dietary risks based on regional background were estimated to compare to Study Area risks for mercury (Table 5-23). Background was only evaluated for mercury because this refined COPC had a LOAEL-based HQ that was greater than 1.0. Background concentrations are presented in Attachment 4. The background HQ for mercury was less than 1.0.

Table 5-23. Comparison of Background and Study Area HQs for Eastern Cottontail

Refined COPC	Unit	Background $Dose_{diet}$[a]	LOAEL TRV	LOAEL-based HQ	
				Background	Study Area
Mercury	mg/kg bw/day	0.0045	0.0084	0.54	**1.2**

[a] Details and sources of background concentrations are presented in Attachment 4. Background soil concentrations for mercury (0.07 mg/kg dw) is based on DEQ's Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002).

bw – body weight
COPC – contaminant of potential concern
DEQ – Oregon Department of Environmental Quality
dw – dry weight
LOAEL – lowest-observed-adverse-effect level
HQ – hazard quotient
TRV – toxicity reference value

5.3.4.2 Uncertainty Analysis

This section presents a discussion of uncertainties associated with the problem formulation and the exposure and effects assessments for Eastern cottontail.

Problem Formulation

The primary uncertainties in the problem formulation for Eastern cottontail are associated with ROC selection and the COPC screen. Eighty-eight chemicals (or chemical sums) were identified as COIs for mammal ROCs, including Eastern cottontail. Effects data for mammals were not available for 32 of the COIs, including 4 metals, 1 PAH, 7 SVOCs, 14 VOCs, and petroleum hydrocarbons. Risks to mammals from exposure to these COIs could not be evaluated.

ROC Selection

There is some uncertainty associated with how well the Eastern cottontail represents other herbivorous mammals that may use Force Lake. Eastern cottontail have a small home range and it was assumed that 100% of their plant diet comes from the wetlands associated with the Study Area. Therefore, Eastern cottontail are expected to be protective of other herbivorous mammals.

COPC Screen

Eighty-eight chemicals (or chemical sums) were identified as COIs for terrestrial ROCs, including Eastern cottontail. Effects data for mammals were not available for 31 of the COIs, including: barium, beryllium, manganese, silver, 7 SVOCs, 14 VOCs, and 6 petroleum hydrocarbon mixtures. Risks to terrestrial mammals from exposure to these COIs could not be evaluated.

Exposure Assessment

Uncertainties in the exposure assessment for Eastern cottontail were associated with the following factors:

- Use of BAFs to estimate prey concentrations
- COPC bioavailability
- Incidental soil ingestion rate
- Inclusion of wetland soil from the intermediate sampling depth

These uncertainties are discussed in detail below.

Selected BAFs

BAFs were used to estimate COPC concentrations in terrestrial plants consumed by Eastern cottontail. Attachment 2 presents the details and assumptions used to select BAFs from the literature. The general uncertainties associated with BAFs are the same general uncertainties for BSAFs presented in Section 5.2.1.2. The variability associated with each BAFs used to estimate Eastern cottontail dietary doses for each of the COPCs was evaluated and is presented in Table 5-24.

Table 5-24. Evaluation of BAF Uncertainties Used in Eastern Cottontail Dietary Calculations

COPC	Evaluation of BAF Variability
Cobalt	The plant BAF of 0.0075 was selected based on EPA (2007a). The variability in cobalt BAFs is unknown.
Copper	The plant BAF of 0.341 was based on a mean BAF reported by Bechtel Jacobs (1998). This value was based on 180 BAFs compiled from multiple sources, ranging from 0.0011 to 7.4. The median BAF was 0.124.
Mercury	The plant BAF of 1.481 was based on a mean BAF reported by Bechtel Jacobs (1998). This value was based on 145 BAFs compiled from multiple sources, ranging from 0.00145 to 12.23. The median BAF was 0.652.
Vanadium	The plant BAF of 0.00485 was based EPA (2007a). The variability in vanadium BAFs from the literature is unknown.
Total PAHs	The plant BAF of 6.15 was based on the average BAF of the two individual PAHs with BAFs (benzo[a]pyrene and naphthalene). Individual PAH BAFs were based on EPA (2007a) and the variability in the BAFs for individual PAHs from the literature is unknown.

BAF – bioaccumulation factor
BSAF – biota-sediment accumulation factor
COPC – contaminant of potential concern
EPA – US Environmental Protection Agency
PAH – polycyclic aromatic hydrocarbon

COPC Bioavailability

Metals may be less bioavailable in ingested sediment than in ingested prey. In calculating the ingested doses, it was assumed that metals were 100% bioavailable, which may overestimate risk if the primary source of the dose is soil. Table 5-25 shows the relative contributions of soil and prey to the total ingested doses. For the COPCs listed in the table, the percent contribution of soil ranged from 1% (for total PAHs) up to 93% (for vanadium). For those COPCs with high percent contribution of soil to the dietary dose (e.g., cobalt and vanadium), risks may be overestimated.

Table 5-25. Percent Contribution of Soil and Tissue to Eastern Cottontail Dietary Dose

Refined COPC	% Contribution to Dose	
	Sediment	Prey Tissue
Cobalt	89	11
Copper	15	85
Mercury	4	96
Vanadium	93	7
Total PAHs	1	99

COPC – contaminant of potential concern

Incidental Soil Ingestion Rate

Ingested doses of refined COPCs were estimated using a SIR of 6.3% based on the black-tailed jackrabbit. Increasing the SIR to 20% would increase HQs by less than 0.2 and would not change risk conclusions.

Inclusion of Wetland Soil Data from the Intermediate Sampling Depth

Wetland soil used in the evaluation of terrestrial ecological ROCs, including the Eastern cottontail included surface soil (0 to 6 inches) from 52 locations, soil collected from an intermediate depth (6 to 12 inches) from 10 locations, and an intermediate depth (6 to 24 inches) from 9 soil berm locations. Eastern cottontail may be exposed to chemicals at the intermediate soil depth less frequently than the surface depth. Table 5-21 presents a comparison of wetland soil EPCs used in the ERA based on UCLs including all surface and intermediate soil data and soil UCLs based only surface soil data. Using only surface samples would not change risk conclusions for Eastern cottontail for all refined COPCs, except for total PAHs; for this COPC, both NOAEL and LOAEL HQs would be less than 1.0 if only surface samples were used to estimate dietary exposure.

Effects Assessment

Uncertainty associated with available toxicity benchmarks for mammals may affect risk estimates. General uncertainties with selected TRVs were presented in Section 5.3.1.2. A summary of the uncertainties for the mammal TRVs for all COPCs evaluated is presented in Table 5-26.

Table 5-26. Uncertainty Associated with Selected TRVs for Mammals

Refined COPC	No. of TRV Studies	Uncertainty in and Selection of TRV
Arsenic	1	selected TRVs were based on single study available; single study available was chronic (2-year study) with good data quality
Cadmium	4	selected TRVs were based on a chronic growth study
Cobalt	3	selected TRVs were based on a subchronic growth endpoint
Copper	3	selected TRVs were based on reproduction endpoint
Lead	2	only one study available with a LOAEL; selected TRVs based on reproduction endpoint
Mercury	3	selected TRVs were based on a chronic growth endpoint; NOAEL extrapolated from LOAEL using an uncertainty factor of 5
Vanadium	2	only two studies available; selected TRVs based on chronic growth endpoint
Zinc	3	selected TRVs were based on a reproduction endpoint
Total PAHs	2	selected TRVs were based on a reproduction endpoint via gavage exposure; NOAEL extrapolated from LOAEL using an uncertainty factor of 5
Total PCBs	13	selected TRVs were based on reproduction endpoint in mice; NOAEL extrapolated from LOAEL based on uncertainty factor of 10
Total DDTs	16	selected TRVs were based on reproduction endpoint

[a] Refined COPC for either mammal receptor (i.e., Eastern cottontail or shrew).

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value

5.3.4.3 Risk Conclusions

Risks to Eastern cottontail were evaluated by comparing estimated dietary doses to dietary TRVs. Seven COPCs were evaluated for Eastern cottontail: aluminum, cobalt, copper, mercury, selenium, vanadium, and total PAHs. Uncertainties in the problem formulation, the effects and exposure assessments, and risk characterization Eastern cottontail were evaluated to arrive at the following risk conclusions:

- **Cobalt, copper, and vanadium:** Risks from these COPCs were negligible because both NOAEL- and LOAEL-based HQs were less than 1.0.
- **Total PAHs:** Risk from total PAHs was low because the NOAEL-based HQ was greater than 1.0 but the LOAEL-based HQ was less than 1.0.
- **Mercury:** The LOAEL-based HQ for mercury was greater than 1.0 (HQ = 1.2), indicating the potential for adverse effects. The background LOAEL-based HQs for mercury was less than 1.0, (HQ = 0.54).

In summary, one COPC (mercury) had LOAEL-based HQs greater than 1.0. Key uncertainties that may affect the Eastern cottontail risk estimates include the use of variable literature-based BAFs for plants, and high uncertainty in TRVs for vanadium and total PAH TRVs.

5.3.5 Shrew

This section present risk characterization, uncertainties, and risk conclusions for shrew.

5.3.5.1 Risk Estimates

Ten refined COPCs were evaluated for shrew: arsenic, cadmium, cobalt, copper, lead, mercury, zinc, total PAHs, total PCBs, and total DDTs. Table 5-27 presents the calculated NOAEL- and LOAEL-based HQs for these refined COPCs.

Table 5-27. Risk Estimates for Shrew

Refined COPC	Unit	$Dose_{diet}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Arsenic	mg/kg bw/day	0.52	2.6	5.4	0.20	0.096
Cadmium	mg/kg bw/day	2.2	3.5	13	0.63	0.17
Cobalt	mg/kg bw/day	0.91	0.1	1	**9.1**	0.91
Copper	mg/kg bw/day	21	18	26	**1.2**	0.81
Lead	mg/kg bw/day	32	11	90	**2.9**	0.36
Mercury	mg/kg bw/day	0.11	0.0017	0.0084	**65**	**13**
Zinc	mg/kg bw/day	190	160	320	**1.2**	0.59
Total PAHs	µg/kg bw/day	2,900	2,000	10,000	**1.5**	0.29
Total PCBs	µg/kg bw/day	730	130	1,300	**5.6**	0.56

Table 5-27. Risk Estimates for Shrew

Refined COPC	Unit	$Dose_{diet}$	TRV		HQ	
			NOAEL	LOAEL	NOAEL	LOAEL
Total DDTs	µg/kg bw/day	11,000	1,200	1,300	**9.2**	**8.5**

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
Bold HQs are greater than 1.0.

NOAEL-based HQs were less than 1.0 for arsenic and cadmium, indicating negligible risk. NOAEL-based HQs for cobalt, copper, lead, zinc, total PAHs, and total PCBs were greater than 1.0; but LOAEL-based HQs were less than 1.0, indicating low risk. Both the NOAEL- and LOAEL-based HQs for mercury and total DDTs were greater than 1.0; NOAEL-based HQs ranged from 9.2 to 65 for these COPCs, and LOAEL-based HQs ranged from 8.5 to 13, indicating a potential for adverse effects.

Dietary risks based on regional background or reference areas were estimated to compare to Study Area risks for those refined COPCs with LOAEL-based HQs greater than 1.0 (Table 5-28). Background and reference area concentrations are presented in Attachment 4. The reference area LOAEL-based HQ for total DDTs was less than 1.0. The Study Area LOAEL-based HQ for mercury (13) was within the range of the background LOAEL-based HQs for mercury (5.7 to 15).

Table 5-28. Comparison of Background and Study Area HQs for Shrew

Refined COPC	Unit	Background or Reference Area $Dose_{diet}$[a]	LOAEL TRV	LOAEL-Based HQ	
				Background or Reference Area	Study Area
Mercury	mg/kg bw/day	0.048 – 0.13	0.0084	**5.7 – 15**	**13**
Total DDTs	µg/kg bw/day	69 – 530	1,300	0.053 – 0.41	**8.5**

[a] Details and sources of background and reference area (urban areas within the vicinity of the Study Area) concentrations are presented in Attachment 4. The range of background soil and sediment concentrations for mercury (0.07 to 0.2 mg/kg dw) was based on DEQ's Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002), and DEQ (2007). The range of soil and sediment reference area concentrations for total DDTs (15 to 355 µg/kg dw) was based on the range of values from DEQ's Columbia Slough Sediment Project (2005) and from the Radio Tower Site (URS 2000).

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
na – not available
PCB – polychlorinated biphenyl
TRV – toxicity reference value
Bold HQs are greater than 1.0.

5.3.5.2 Uncertainty Analysis

This section presents a discussion of uncertainties associated with the problem formulation and the exposure and effects assessments for shrew.

Problem Formulation

Primary uncertainties in the problem formulation for shrew are associated with ROC selection and the COPC screen. Uncertainties in the COPC screen for terrestrial mammals were discussed in Section 5.3.4.2. The shrew was selected to represent mammals at the Study Area that consume invertebrates. While the habitat type at the Study Area is suitable for shrew, shrew have not been observed at the Study Area (Table 2-4) or at the nearby Vanport wetlands (Port of Portland 2004), and thus there is uncertainty with the selection of shrew as a relevant mammal ROC for the Study Area.

Exposure Assessment

Uncertainties in the exposure assessment for shrew were associated with the following factors:

- Use of BSAFs and BAFs to estimate prey concentrations
- COPC bioavailability
- Incidental soil and sediment ingestion rates

These uncertainties are discussed in detail below.

Selected BSAFs and BAFs

Shrew consume both aquatic (30%) and terrestrial (70%) invertebrates as part of their diet. BSAFs were used to estimate aquatic invertebrate prey tissue concentrations for shrew and BAFs were used to estimate terrestrial prey tissue concentrations. Attachment 2 presents the details and assumptions used to select BSAFs and BAFs from the literature. The general uncertainties associated with BSAFs and BAFs were presented in Section 5.2.1.2. The variability associated with each BSAF and BAF used to estimate shrew dietary doses for each of the refined COPCs was evaluated and is presented in Tables 5-29 and 5-30, respectively.

Table 5-29. Evaluation of Variability in BSAFs Used in Shrew Dietary Calculations for Ingestion of Aquatic Invertebrates

Refined COPC	Evaluation of BSAF Variability
Arsenic	The invertebrate BSAF of 0.240 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 49 BSAFs compiled from multiple sources, ranging from 0.018 to 0.889. The median BSAF was 0.127.
Cadmium	The invertebrate BSAF of 3.438 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 88 BSAFs compiled from multiple sources, ranging from 0.049 to 41.55. The median BSAF was 0.614.
Cobalt	No invertebrate BSAF was available from the literature for cobalt so a default BAF of 1 was used.
Copper	The invertebrate BSAF of 2.14 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 74 BSAFs compiled from multiple sources, ranging from 0.032 to 16.63. The median BSAF was 1.647.
Lead	The invertebrate BSAF of 0.331 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 83 BSAFs compiled from multiple sources, ranging from 0.004 to 7.08. The median BSAF was 0.066.
Mercury	The invertebrate BSAF of 1.204 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 13 BSAFs compiled from multiple sources, ranging from 0.286 to 2.868. The median BSAF was 1.081.
Zinc	The invertebrate BSAF of 3.473 was based on non-depurated mean BSAF reported by ORNL (1998). This value was based on 84 BSAFs compiled from multiple sources, ranging from 0.026 to 14.512. The median BSAF was 2.33.
Total PAHs	The invertebrate BSAF of 0.923 was based on the mean of the average BSAFs for individual PAHs with BSAFs reported in EPA's BSAF database (EPA 2008). Individual PAH BSAFs in EPA's BSAF database ranged from 0.00004 to 37.
Total PCBs	The invertebrate BSAF of 2.57 was based on the average BSAF reported in EPA's BSAF database (EPA 2008). Total PCB BSAFs in EPA's BSAF database ranged from 0.0072 to 28. The median BSAF was 1.3.
Total DDTs	The invertebrate BSAF of 5.21 was based on the weighted average BSAF of the three DDT metabolites detected in sediment: 2,4,-DDD, 4,4-DDD, and 4,4'-DDE. BSAFs for DDT metabolites (4.32 for 2,4,-DDD and 4,4-DDD and 5.94 for 4,4-DDE) were based on EPA's BSAF database (EPA 2008). DDT metabolite BSAFs in EPA's BSAF database ranged from 0.034 to 49. The median BSAFs for 4,4-DDD and 4,4-DDE were 0.62 and 2.9, respectively.

BSAF – biota-sediment accumulation factor
COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
EPA – US Environmental Protection Agency
ORNL – Oak Ridge National Laboratory
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

Table 5-30. Evaluation of Variability in BAFs Used in Shrew Dietary Calculations for Ingestion of Terrestrial Invertebrates

Refined COPC	Evaluation of BAF Variability
Arsenic	The invertebrate BAF of 0.258 was based on the mean BAF reported by Lockheed-Martin Energy Systems (1998). This value was based on 53 BAFs compiled from multiple sources, ranging from 0.006 to 0.925. The median BAF was 0.224.
Cadmium	The invertebrate BAF of 17.105 was based on the mean BAF reported by Lockheed-Martin Energy Systems (1998).This value was based on 226 BAFs compiled from multiple sources, ranging from 0.253 to 190. The median BAF was 7.708.
Cobalt	The invertebrate BAF of 0.122 was based on the BAF reported by reported in EPA (2007a). The variability in cobalt BAFs from the literature is unknown.
Copper	The invertebrate BAF of 0.754 was based on the mean BAF reported by Lockheed-Martin Energy Systems (1998). This value was based on 197 BAFs compiled from multiple sources, ranging from 0.002 to 5.492. The median BAF was 0.515.
Lead	The invertebrate BAF of 3.342 was based on the mean BAF reported by Lockheed-Martin Energy Systems (1998). This value was based on 245 BAFs compiled from multiple sources, ranging from 0 to 228.261. The median BAF was 0.266.
Mercury	The invertebrate BAF of 5.231 was based on the mean BAF reported by Lockheed-Martin Energy Systems (1998). This value was based on 30 BAFs compiled from multiple sources, ranging from 0.030 to 33. The median BAF was 1.693.
Zinc	The invertebrate BAF of 5.766 was based on the mean BAF reported by Lockheed-Martin Energy Systems (1998). This value was based on 244 BAFs compiled from multiple sources, ranging from 0.025 to 49.51. The median BAF was 3.201.
Total PAHs	The invertebrate BAF of 2.87 was based on the average BAF of the two individual PAHs with BAFs (benzo[a]pyrene and naphthalene). Individual PAH BAFs were based on EPA (2007a) and the variability in the BAFs for individual PAHs from the literature is unknown.
Total PCBs	The invertebrate BAF of 8.909 was based on the mean BAF reported by Lockheed-Martin Energy Systems (1998). This value was based on 32 BAFs compiled from multiple sources, ranging from 0 to 65.227. The median BAF was 6.667.
Total DDTs	The invertebrate BAF of 11.2 was based on the BAF reported by reported by EPA (2007a). The variability in total DDT BAFs from the literature is unknown.

BAF – bioaccumulation factor
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
EPA – US Environmental Protection Agency
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

COPC Bioavailability

Metals may be less bioavailable in ingested sediment than in ingested prey. In calculating the ingested doses, it was assumed that metals were 100% bioavailable, which may have overestimated the risk if the primary source of the dose was soil. Table 5-31 shows the relative contributions of soil and prey to the total ingested doses. For the refined COPCs listed in the table, the percent contribution of soil ranged from 1% (for cadmium) up to 37% (for arsenic). Risks may be overestimated for those refined

COPCs with high percent contribution of soil to the dietary dose (e.g., arsenic and cobalt).

Table 5-31. Percent Contribution of Soil and Tissue to Shrew Dietary Dose

Refined COPC	Percent Contribution to Dose	
	Soil	Prey Tissue
Arsenic	37	63
Cadmium	1	99
Cobalt	28	72
Copper	14	86
Lead	5	95
Mercury	3	97
Zinc	3	97
Total PAHs	6	94
Total PCBs	2	98
Total DDTs	2	98

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl

Incidental Sediment Ingestion Rate

Ingested doses of refined COPCs for shrew were conservatively estimated using an SIR of 13%. Increasing the SIR to 20% would increase HQs by less than 0.5 and would not change risk conclusions.

Inclusion of Wetland Soil Data from the Intermediate Sampling Depth

Wetland soil used in the evaluation of terrestrial ecological ROCs, including the shrew, included surface soil (0 to 6 in.) from 52 locations, soil collected from an intermediate depth (6 to 12 in.) from 10 locations, and soil collected from an intermediate depth (6 to 24 in.) from 9 soil berm locations. Shrew may be exposed to chemicals at the intermediate soil depth less frequently than at the surface depth. Table 5-21 presents a comparison of wetland soil EPCs used in the ERA based on UCLs, including all surface and intermediate soil data and soil UCLs based only on surface soil data. Using only surface samples would not change risk conclusions for shrew for all refined COPCs, except for copper and zinc; for these two refined COPCs, both NOAEL and LOAEL HQs would be less than 1.0 if only surface samples were used to estimate dietary exposure.

Effects Assessment

Uncertainties associated with available toxicity benchmarks for mammals are discussed in Section 5.3.4.2.

5.3.5.3 Risk Conclusions

Risks to shrew were evaluated by comparing estimated dietary doses to dietary TRVs. Ten refined COPCs were evaluated for shrew: arsenic, cadmium, cobalt, copper, lead, mercury, zinc, total PAHs, total PCBs, and total DDTs. Uncertainties in the problem formulation, the effects and exposure assessments, and risk characterization shrew were evaluated to arrive at the following risk conclusions for each refined COPC:

- **Arsenic and cadmium:** Risks from these COPCs were negligible because both NOAEL- and LOAEL-based HQs were less than 1.0.
- **Cobalt, copper, lead, zinc, total PAHs, and total PCBs:** Risk from these COPCs were low because the NOAEL-based HQs were greater than 1.0 but the LOAEL-based HQs were less than 1.0.
- **Mercury:** The LOAEL-based HQ for mercury was greater than 1.0 (HQ = 13), indicating the potential for adverse effects. However, the background LOAEL-based HQ ranged from 5.7 to 15, indicating that background concentrations are an important consideration in evaluating Study Area risks from mercury.
- **Total DDTs:** The LOAEL-based HQ for total DDTs was greater than 1.0 (HQ = 8.5), indicating the potential for adverse effects. The reference area LOAEL-based HQs were less than 1.0.

In summary, one refined COPCs had a LOAEL-based HQ greater than 1.0: total DDTs. Other key uncertainties that may affect the risk estimates include the use of the site by shrew and the use of variable literature-based BAFs and BSAFs, and high uncertainty in TRVs for lead and total PAH TRVs.

The risks to shrew based on exposure to total DDTs were further evaluated. To further evaluate risks to shrew for total DDTs, a map was created to evaluate the spatial extent of areas resulting in LOAEL-based HQs greater than 1.0 (Figure 5-2). Although shrew were assumed to consume both aquatic and terrestrial invertebrates, the majority of their COPC exposure (> 99%) can be attributed to total DDT concentrations in wetland soil (i.e., through the terrestrial food chain). Thus, Figure 5-2 presents only the COPC concentrations in wetland soil.

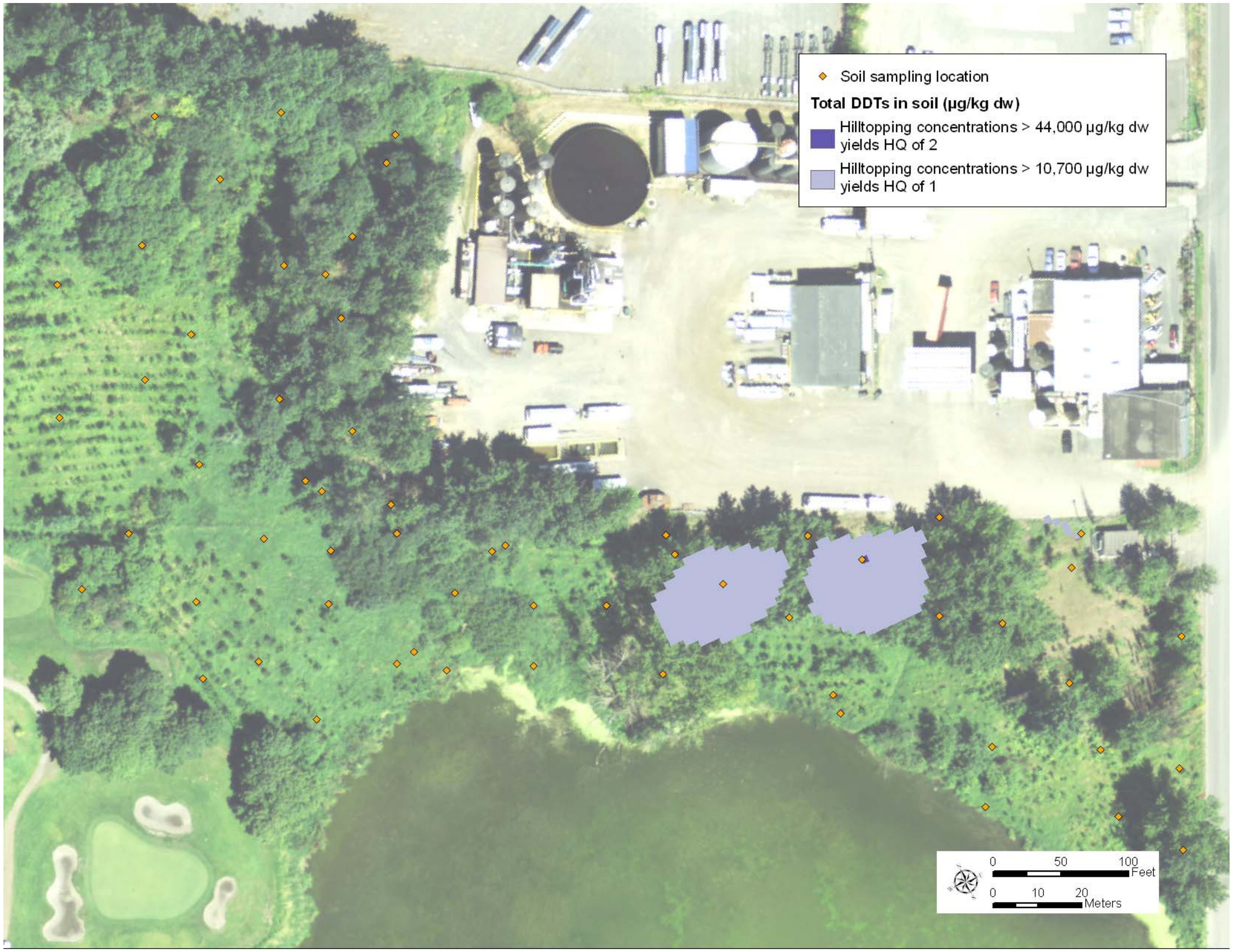


Figure 5-2. Natural Neighbors Interpolation of Total DDTs in Soil Relative to Risks to Shrew

As can be seen in Figure 5-2, areas causing risks to shrew from total DDTs are limited in spatial extent. The figure was created by replacing the highest sediment concentrations with reference area concentrations to reduce the overall wetland EPC such that risks to shrew would be less than a LOAEL-based HQ of 1.0. The range of reference area concentrations for total DDTs (15 to 355 µg/kg dw) was based on the range of soil values from the Radio Tower Site (URS 2000).

In the case of total DDTs, if the average concentration in soil were less than 978 µg/kg dw, then the risk to shrew from total DDT exposure would be low (less than a LOAEL-based HQ of 1.0). An average total DDT concentration of less than 978 µg/kg dw could be achieved by “replacing” the 3 wetland sampling locations with soil concentrations greater than 10,700 µg/kg dw, with a soil concentration of 355 µg/kg dw. The replacement concentration of 355 µg/kg dw is based on the high end of the range of total DDTs reference area concentrations from soil collected at the Radio Tower Site. The three areas with total DDT concentrations that had concentrations greater than 10,700 µg/kg dw are shaded purple on Figure 5-3. The single small, darker purple area indicates where total DDT soil concentrations were highest (i.e., greater than 44,000 µg/kg dw), which, if removed, would result in an HQ of 2.0 based on the average DDT concentration).

6.0 CONCLUSIONS

This baseline ERA characterizes ecological risks in support of risk management decisions and evaluation of remedial options. ROCs evaluated in this ERA included aquatic and terrestrial invertebrates, fish (pumpkinseed, brown bullhead), aquatic and terrestrial birds (ruddy duck, great blue heron, red-tailed hawk), and mammals (Eastern cottontail and shrew). Individual species selected as ROCs (e.g., brown bullhead, shrew) were selected as representative surrogate species to be protective of their respective feeding guilds (e.g., omnivorous fish, invertivorous mammals).COPCs with LOAEL-based HQs greater than or equal to 1.0 for each of these receptor groups are summarized in Table 6-1.

Table 6-1. Refined COPCs and Refined COPCs with LOAEL-Based HQs ≥ 1.0 for Each ROC Group

ROC Group	Refined COPCs	Refined COPCs with LOAEL-Based HQ ≥ 1.0[a]
Aquatic benthic invertebrates	cadmium, copper, lead, nickel, zinc, 2 individual PAHs, total PCBs, 2,4′-DDD, 4,4′-DDD, 4,4′-DDT, total DDTs	2,4′-DDD, 4,4′-DDD, 4,4′-DDE
Terrestrial invertebrates[b]	chromium, copper, mercury, zinc, HPAHs	chromium, copper, zinc, HPAHs
Fish ROCs	total PCBs, cadmium, copper	copper
Aquatic bird ROCs	mercury total DDTs	none
Terrestrial bird ROCs	total DDTs	total DDTs
Mammal ROCs	arsenic, cadmium, cobalt, copper, lead, mercury, vanadium, zinc, total PAHs, total PCBs, total DDTs	mercury, total DDTs

[a] LOAEL-based HQ ≥ 1.0 or exceedance of the PEC/PEL.

[b] HQs for terrestrial invertebrates were based on conservative screening values that may include no-effects data.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
LOAEL – lowest-observed-adverse-effect level
HQ – hazard quotient
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
ROC – receptor of concern
TRV – toxicity reference values

Risks from most of the COPCs were found to be negligible (NOAEL and LOAEL HQs were < 1.0) or low (NOAEL HQs were ≤ 1.0, but LOAEL HQs were < 1.0), especially taking into account a comparison of Study Area concentrations to background concentrations. Risk conclusions for each of the receptor groups are briefly summarized below and risk estimates are summarized in Table 6-2 for each of the COPCs.

Table 6-2. Summary of Baseline ERA Risk Estimates and Conclusions

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Exposure Value[a]	NOAEL TRV	LOAEL TRV	Chemical Form; Endpoint	Risk Conclusions[b]
Aquatic Benthic Invertebrate Community							
Cadmium (sediment)	**3.4 – 3.4**[c]	0.57 – 0.57[d]	2,000 – 2,000 mg/kg	596 mg/kg[c]	3,530 mg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
Copper (sediment)	0.51 – **2.3**[c]	0.11 – 0.48[d]	16,200 – 72,000 mg/kg	31,600 mg/kg[c]	149,000 mg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
Lead (sediment)	0.26 – **1.6**[c]	0.099 – 0.61[d]	9,000 – 56,000 mg/kg	35,000 mg/kg[c]	91,300 mg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
Nickel (sediment)	0.61 – **1.7**[c]	0.31 – 0.86[d]	11,000 – 31,000 mg/kg	18,000 mg/kg[c]	36,000 mg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
Zinc (sediment)	0.66 – **1.9**[c]	0.25 – 0.73[d]	80,000 – 229,000 mg/kg	121,000 mg/kg[c]	315,000 mg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
Fluoranthrene (sediment)	0.18 – **1.7**[c]	0.009 – 0.085[d]	20 – 190 µg/kg	111 µg/kg[c]	2,230 µg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
Phenanthrene (sediment)	0.36 – **2.9**[c]	0.029 – 0.23[d]	15 – 120 µg/kg	41.9 µg/kg[c]	515 µg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
Total PCBs (sediment)	**2.7 – 3.8**[c]	0.34 – 0.47[d]	93 – 131 µg/kg	34.1 µg/kg[c]	277 µg/kg[d]	na[e]	low risk because although HQ based on conservative TEL/TEC is > 1.0, HQ based on PEL/PEC is < 1.0
DDD (sediment)	**2.4 – 17**[c]	1.0 – **7.2**[d]	8.6 – 61 µg/kg	3.54 µg/kg[c]	8.51 µg/kg[d]	na[e]	potential for adverse effects; however, risk estimates are uncertain given that the high TOC in the lake may limit bioavailability and that although individual DDT metabolites were greater than the PEC/PEL (indicating risk), total DDT concentrations were less than the PEC/PEL threshold (indicating low risk)
DDE (sediment)	**6.4 – 110**[c]	**1.3 – 22**[d]	9.1 – 150 µg/kg	1.42 µg/kg[c]	6.75 µg/kg[d]	na[e]	
Total DDTs (sediment)	**4.2 – 47**[c]	0.038 – 0.44[d]	22 – 250 µg/kg	5.28 µg/kg[c]	572 µg/kg[d]	na[e]	

Table 6-2. Summary of Baseline ERA Risk Estimates and Conclusions

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Exposure Value[a]	NOAEL TRV	LOAEL TRV	Chemical Form; Endpoint	Risk Conclusions[b]
Terrestrial Invertebrate Community							
Chromium	**3.3 – 75**[f]		6.6 – 149	2[f]		potassium dichromate; survival	potential for adverse effects; however, risk estimates are uncertain because they are based on a conservative screening level value that assumes 100% bioavailability and are based on exposure to chromium (VI), whereas Cr (III) is more commonly found in the natural environment; the conservative screening level (2 mg/kg dw) is 21 times greater than the background soil concentration (42 mg/kg dw); only 18% of the soil samples (13/71), primarily in wetland soils collected from or near the ditch area, exceeded the background soil chromium concentration of 42 mg/kg dw
Copper	0.21 – **25**[f]		10.3 – 1,240 mg/kg	50 mg/kg[f]		unknown form; multiple effects	potential for adverse effects; however, risk estimates are uncertain because they are based on a conservative screening level value that assumes 100% bioavailability; Study Area concentrations were greater than the conservative screening level in 27 of 71 samples (38%), highest concentrations were primarily in wetland soil collected from or near the ditch area
Mercury	0.08 to 0.8[f]		0.04 – 0.4 mg/kg	0.5 mg/kg[f]		mercury chloride; survival	negligible risk because HQs are < 1.0; risk estimates are based on a published conservative screening level value that likely overpredicts risk because it assumes 100% bioavailability

Table 6-2. Summary of Baseline ERA Risk Estimates and Conclusions

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Exposure Value[a]	NOAEL TRV	LOAEL TRV	Chemical Form; Endpoint	Risk Conclusions[b]
Zinc	0.31 – **6.2**[f]		37 – 748 mg/kg	120 mg/kg[f]		unknown form; reproduction	potential for adverse effects; however, risk estimates are uncertain because they are based on a conservative screening level value that assumes 100% bioavailability; Study Area concentrations were greater than the conservative screening level in 49 of 71 samples (69%); highest concentrations primarily were in wetland soils collected from or near the ditch area
Total HPAHs	0.0056 **– 3.2**[f]		0.101 – 57 mg/kg	18 mg/kg[f]		phenanthrene, fluorene, or fluoranthene; reproduction/ growth	potential for adverse effects; however, risk estimates are uncertain because they are based on a conservative screening level value that assumes 100% bioavailability; Study Area concentrations were greater than conservative screening level (HQs of 1.3 and 3.2) in only 2 of 71 samples (3%)
Pumpkinseed							
Cadmium (diet)	0.047	0.033	0.15 mg/kg bw/day	3.2 mg/kg bw/day	4.6 mg/kg bw/day	cadmium chloride; reproduction	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Copper (diet)	**3.5**	**1.8**	3.5 mg/kg bw/day	1 mg/kg bw/day	2 mg/kg bw/day	copper sulfate; growth	potential for adverse effects because LOAEL HQ is > 1.0, although magnitude of exceedance (LOAEL HQ is 1.8) is small
Total PCBs (tissue)	**2.7**	0.54	280 µg/kg	104 µg/kg	520 µg/kg	Aroclor 1260; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Brown Bullhead							
Cadmium (diet)	0.028	0.019	0.089 mg/kg bw/day	3.2 mg/kg bw/day	4.6 mg/kg bw/day	cadmium chloride; reproduction	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Copper (diet)	**2.1**	**1.1**	2.1 mg/kg bw/day	1 mg/kg bw/day	2 mg/kg bw/day	copper sulfate; growth	potential for adverse effects because LOAEL HQ is > 1.0, although magnitude of exceedance (LOAEL HQ is 1.1) is small

Table 6-2. Summary of Baseline ERA Risk Estimates and Conclusions

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Exposure Value[a]	NOAEL TRV	LOAEL TRV	Chemical Form; Endpoint	Risk Conclusions[b]
Total PCBs (tissue)	**2.2**	0.44	230 µg/kg	104 µg/kg	520 µg/kg	Aroclor 1260; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Ruddy Duck							
Mercury	**1.1**	0.21	0.0019 mg/kg bw/day	0.018 mg/kg bw/day	0.091 mg/kg bw/day	methylmercury chloride; growth	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Total DDTs	0.91	0.18	58 µg/kg bw/day	64 µg/kg bw/day	320 µg/kg bw/day	DDE; reproduction	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Great Blue Heron							
Total DDTs	0.83	0.17	53 µg/kg bw/day	64 µg/kg bw/day	320 µg/kg bw/day	DDE; reproduction	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Red-Tailed Hawk							
Total DDTs	**5.8**	**1.2**	370 µg/kg bw/day	64 µg/kg bw/day	320 µg/kg bw/day	DDE; reproduction	potential for adverse effects because LOAEL HQ is > 1.0, although magnitude of exceedance is small (LOAEL HQ is 1.2)
Eastern Cottontail							
Cobalt	0.35	0.035	0.035 mg/kg bw/day	0.1 mg/kg bw/day	1 mg/kg bw/day	cobalt chloride; growth	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Copper	0.14	0.10	2.6 mg/kg bw/day	18 mg/kg bw/day	26 mg/kg bw/day	copper sulfate; reproduction	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Mercury	**5.9**	**1.2**	0.010 mg/kg bw/day	0.0017 mg/kg bw/day	0.0084 mg/kg bw/day	methymercuric chloride; growth	potential for adverse effects because LOAEL HQ is > 1.0, although magnitude of exceedance is small (LOAEL HQ is 1.2); note also that the LOAEL HQ based on the background concentration is 0.54, which accounts for half of the Study Area LOAEL HQ of 1.2

Table 6-2. Summary of Baseline ERA Risk Estimates and Conclusions

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Exposure Value[a]	NOAEL TRV	LOAEL TRV	Chemical Form; Endpoint	Risk Conclusions[b]
Vanadium	0.78	0.078	0.21 mg/kg bw/day	0.27 mg/kg bw/day	2.7 mg/kg bw/day	sodium metavanadate; growth	negligible risk because both NOAEL and LOAEL HQa are < 1.0
Total PAHs	**1.1**	0.22	2,200 µg/kg bw/day	2,000 µg/kg bw/day	10,000 µg/kg bw/day	benzo(a)pyrene; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Shrew							
Arsenic	0.20	0.096	0.52 mg/kg bw/day	2.6 mg/kg bw/day	5.4 mg/kg bw/day	sodium arsenate; growth	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Cadmium	0.63	0.17	2.2 mg/kg bw/day	3.5 mg/kg bw/day	13 mg/kg bw/day	cadmium chloride; growth	negligible risk because both NOAEL and LOAEL HQs are < 1.0
Cobalt	**9.1**	0.91	0.91 mg/kg bw/day	0.1 mg/kg bw/day	1 mg/kg bw/day	cobalt chloride; growth	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Copper	**1.2**	0.81	21 mg/kg bw/day	18 mg/kg bw/day	26 mg/kg bw/day	copper sulfate; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Lead	**2.9**	0.36	32 mg/kg bw/day	11 mg/kg bw/day	90 mg/kg bw/day	lead acetate; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Mercury	**65**	**13**	0.11 mg/kg bw/day	0.0017 mg/kg bw/day	0.0084 mg/kg bw/day	methymercuric chloride; growth	potential for adverse effects because LOAEL HQ is > 1.0; note also that the LOAEL HQs based on background concentrations ranged from 5.7 to 15, which are similar to the Study Area LOAEL HQ of 13
Zinc	**1.2**	0.59	190 mg/kg bw/day	160 mg/kg bw/day	320 mg/kg bw/day	zinc oxide; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Total PAHs	**1.5**	0.29	2,900 µg/kg bw/day	2,000 µg/kg bw/day	10,000 µg/kg bw/day	benzo(a)pyrene; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0

Table 6-2. Summary of Baseline ERA Risk Estimates and Conclusions

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Exposure Value[a]	NOAEL TRV	LOAEL TRV	Chemical Form; Endpoint	Risk Conclusions[b]
Total PCBs	**5.6**	0.56	730 µg/kg bw/day	130 µg/kg bw/day	1,300 µg/kg bw/day	Aroclor 1254; reproduction	low risk because although NOAEL HQ is > 1.0, LOAEL HQ is < 1.0
Total DDTs	**9.2**	**8.5**	11,000 µg/kg bw/day	1,200 µg/kg bw/day	1,300 µg/kg bw/day	total DDTs; reproduction	potential for adverse effects because LOAEL HQ is > 1.0; highest areas contributing to risk are spatially limited to a few highly localized areas in the wetland

a Exposure value is presented as the range of detected concentrations for aquatic benthic invertebrates and terrestrial invertebrates. The exposure value for fish, bird, and mammal receptors is the 95th UCL concentration.

b The potential for adverse effects is identified for those ROC-COPC pairs for which the LOAEL HQ is ≥ 1.0. Low risk is defined as NOAEL HQ is > 1.0, but LOAEL HQ is < 1.0. Negligible risk is defined as NOAEL HQ is ≤ 1.0.

c HQs were developed based on a comparison with a TEL or a TEC.

d HQs were developed based on a comparison with a PEL or a PEC.

e Sediment TRVs are consensus-based thresholds (TECs and PECs) and sediment quality guidelines (TELs and PELs) that take into account numerous laboratory studies, field studies, and toxicity models.

f HQs were developed based on a comparison with soil screening levels.

bw – body weight
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
ERA – ecological risk assessment
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
na – not applicable
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
TEC – threshold effects concentration
TEL – threshold effects level
TRV – toxicity reference value

Bold identifies HQs greater than 1.0.

Aquatic Benthic Invertebrate Community: Concentrations of refined COPCs (including metals, PAHs, PCBs, and total DDTs) were greater than threshold effects concentrations (TECs) or threshold effects levels (TELs) but less than probable effects concentrations (PECs) or probable effects levels (PELs). TELs and TECs are highly conservative concentrations below which adverse effects on sediment-dwelling organisms are not expected. Exceedances of TECs and TELs do not necessarily predict toxicity; therefore, risks to benthic invertebrates are expected to be low because these COPCs had concentrations greater than TECs/TELs but less than PECs/PELs. DDD and DDE were the only refined COPCs with concentrations in sediment that were also greater than PECs or PELs (thresholds associated with adverse effects); however, total DDT concentrations were less than these thresholds, and the bioavailability of DDD and DDE would be limited because total organic carbon concentrations in the sediment were high, reducing the likelihood of effects on biota. No refined COPCs were identified for surface water; therefore, no risks to the aquatic benthic invertebrate community from exposure to surface water are expected.

As part of the uncertainty analysis, the potential exposure of aquatic benthic invertebrates to chemicals detected in nearby wetland soils and in shallow groundwater wells closest to Force Lake was evaluated. It was determined that shallow groundwater along the downgradient (i.e., south) side of the Facility is not expected to be a significant pathway of exposure for aquatic benthic invertebrates. Also, the potential for unacceptable risk to aquatic benthic invertebrates from the potential erosion of wetland soils into the lake is minimal because: 1) metals and PCB concentrations in wetland soils near Force Lake were low compared with PELs and PECs, and 2) total DDT concentrations in lake sediment were much lower than those in wetland soils likely indicating limited transport of wetland soils to Force Lake.

Terrestrial Invertebrate Community: Four refined COPCs (chromium, copper, zinc, and total HPAHs) were evaluated for the terrestrial invertebrate community. HQs were less than 6.5, except for copper (with HQs from 0.21 to 25 and a background HQ of 0.72) and chromium (with HQs from 3.3 to 75 and a background HQ of 21). This assessment likely overestimated risk because the soil screening levels are conservative thresholds intended for screening only (i.e., they are not intended to serve as cleanup values); they do not take into account site-specific bioavailability. The conservative screening level used for chromium is 21 times greater than the background soil concentration. In addition, although soil concentrations were greater than soil TRVs for these refined COPCs, earthworms were frequently observed during field sampling, including in those areas where metals concentrations were highest. The samples with concentrations greater than background concentrations and conservative screening values were relatively limited, with the highest concentrations found in wetland soil collected from or near the ditch area.

Fish: Three measures of assessment were evaluated for the two fish ROCs, pumpkinseed and brown bullhead: tissue-residue, surface water, and dietary dose. Three refined COPCs were evaluated (total PCBs in tissue and cadmium and copper in diet). Of these three COPCs, only copper had an exposure concentration greater than the LOAEL TRV, indicating the potential for adverse effects; however, the LOAEL-based HQs were low (1.8 for pumpkinseed and 1.1 for brown bullhead).Consistent with the uncertainty evaluation conducted for the aquatic benthic invertebrate community, the potential for exposure to fish from shallow groundwater discharging into Force Lake is not expected to be a significant pathway of exposure.

Uncertainties that may affect the fish ROC risk estimates include the use of literature-based BSAFs (effect on risk estimates is unknown) and the selected dietary composition for pumpkinseed (risks may be overestimated based on the assumption of aquatic benthic invertebrates prey).

Birds: For birds (ruddy duck, great blue heron, and red-tailed hawk), two COPCs (mercury and total DDTs) were evaluated based on the results of the refined COPC screen. Estimated dietary doses for mercury were less than those associated with adverse effects. The LOAEL-based HQ for total DDT for the red-tailed hawk was 1.2, indicating the potential for adverse effects.

Uncertainties that may have affected the risk estimates include the use of literature-based BSAFs and BAFs (effect on risk estimates is unknown).

Mammals: For mammals (Eastern cottontail and shrew), 11 COPCs were evaluated based on the refined COPC screen. For Eastern cottontail, LOAEL-based HQs for mercury (1.2) were greater than 1.0, indicating the potential for adverse effects. However, the background LOAEL-based HQ for mercury (0.54) was half that of the Study Area HQ, indicating that background contributions to the risk estimate were significant.

For shrew, LOAEL-based HQs for mercury (13) and total DDTs (8.5) were greater than 1.0, indicating the potential for adverse effects. The background LOAEL-based HQs for mercury ranged from 5.7 to 15 (compared with a Study Area HQ of 13), indicating that background is an important consideration when evaluating risks for mercury. Reference area LOAEL-based HQs for total DDTs were less than 1.0.

Uncertainties that may affect the mammal risk estimates include the use of the site by shrew, and the use of literature-based BAFs and BSAFs.

To further evaluate risks to shrew from total DDTs, a map was created to evaluate the spatial extent of areas with concentrations that resulted in LOAEL-based HQs greater than 1.0. Shrew were assumed to consume both aquatic and terrestrial invertebrates; however, the majority of their COPC exposure (> 99%) can be attributed to total DDT concentrations in wetland soil (i.e., through the terrestrial food chain). Wetland areas with total DDT concentrations that resulted in area-wide HQs greater than 1.0 were limited to a few highly localized areas, generally within the central portion of the wetlands between the Facility and Force Lake.

Table 6-3 summarizes the HQs for all ecological ROCs for which the LOAEL-based or PEL- or PEC-based HQs were greater than 1.0. Table 6-3 presents HQs based on Study Area data as well as effects-based HQs derived using background or reference area concentrations.

Table 6-3. Refined COPCs and ROCs with LOAEL-Based HQs Greater than 1.0

Refined COPC	NOAEL-Based HQ	LOAEL-Based HQ	Background or Reference Area LOAEL-Based HQ[a]
Aquatic Benthic Invertebrate Community			
DDD	**2.4 – 17**[b]	1.0 **– 7.2**[c]	0.072 – 0.79[c]
DDE	**6.4 – 110**[b]	**1.3 – 22**[c]	1.0 – **1.5**[c]
Terrestrial Invertebrate Community			
Chromium	**3.3 – 75**[e]		**21**
Copper	0.21 – **25**[e]		0.72
Zinc	0.31 – **6.2**[e]		0.72
Total HPAHs	0.0056 **– 3.2**[e]		0.003 – 0.022
Fish – Pumpkinseed			
Copper	**3.5**	**1.8**	0.30
Fish – Brown Bullhead			
Copper	**2.1**	**1.1**	0.18
Birds – Red-Tailed Hawk			
Total DDTs	**5.8**	**1.2**	0.020 – 0.47
Mammals – Eastern Cottontail			
Mercury	**5.9**	**1.2**	0.54
Mammals – Shrew			
Mercury	**65**	**13**	**5.7 – 15**
Total DDTs	**9.2**	**8.5**	0.053 – 0.41

a Background and reference area (urban areas within the vicinity of the Study Area) concentrations and sources are discussed in Attachment 4. Concentrations for metals are representative of background concentrations, and concentrations for organic compounds are representative of reference area concentrations.

b HQs were developed based on a comparison with a TEL or a TEC.

c HQs were developed based on a comparison with a PEL or a PEC; total DDT concentrations were less than the total DDT PEL/PEC.

d HQs were developed based on a comparison with soil screening levels.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
HQ – hazard quotient
LOAEL – lowest-observed-adverse-effect level
na – not applicable
NOAEL – no-observed-adverse-effect level
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
ROC – receptor of concern
TEC – threshold effects concentration
TEL – threshold effects level
TRV – toxicity reference value

Bold identifies HQs greater than 1.0.

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Attachment 1: Summary of Screening Thresholds and TRVs

Table 1. Summary of Aquatic Benthic Invertebrate Sediment Thresholds

Sediment COI	Sediment Threshold				Source of Selected Sediment Thresholds
	TEC[a]	TEL[b]	PEC[a]	PEL[b]	
Metals (mg/kg dw)					
Arsenic	9.79	**5.9**	33	**17**	Smith et al. (1996)
Cadmium	0.99	**0.596**	4.98	**3.53**	Smith et al. (1996)
Chromium	43.4	**37.3**	111	**90**	Smith et al. (1996)
Copper	**31.6**	35.7	**149**	197	MacDonald et al. (2000)
Lead	35.8	**35**	128	**91.3**	Smith et al. (1996)
Mercury	0.18	**0.174**	1.06	**0.486**	Smith et al. (1996)
Nickel	22.7	**18**	48.6	**36**	Smith et al. (1996)
Zinc	**121**	123	459	**315**	MacDonald et al. (2000); Smith et al. (1996)
PAHs (µg/kg dw)					
Anthracene	**57.2**	na	**845**	na	MacDonald et al. (2000)
Benzo(a)anthracene	108	**31.7**	1,050	**385**	Smith et al. (1996)
Benzo(a)pyrene	150	**31.9**	1,450	**782**	Smith et al. (1996)
Chrysene	166	**57.1**	1,290	**862**	Smith et al. (1996)
Dibenzo(a,h)anthracene	**33**	na	na	na	MacDonald et al. (2000)
Fluoranthene	423	**111**	**2,230**	2,355	Smith et al. (1996); MacDonald et al. (2000)
Fluorene	**77.4**	na	**536**	na	MacDonald et al. (2000)
Naphthalene	**176**	na	**561**	na	MacDonald et al. (2000)
Phenanthrene	204	**41.9**	1,170	**515**	Smith et al. (1996)
Pyrene	195	**53**	1,520	**875**	Smith et al. (1996)
Total PAHs	**1,610**	na	**22,800**	na	MacDonald et al. (2000)
PCBs(µg/kg dw)					
Total PCBs	59.8	**34.1**	676	**277**	Smith et al. (1996)
Pesticides (µg/kg dw)					
2,4'-DDD	4.88	**3.54**	28	**8.51**	Smith et al. (1996)
4,4'-DDD	4.88	**3.54**	28	**8.51**	Smith et al. (1996)
4,4'-DDE	3.16	**1.42**	31.3	**6.75**	Smith et al. (1996)
Total DDTs	**5.28**	7	**572**	4,450	MacDonald et al. (2000)
Chlordane	**3.24**	4.5	17.6	**8.9**	MacDonald et al. (2000); Smith et al. (1996)
Dieldrin	**1.9**	2.85	61.8	**6.67**	MacDonald et al. (2000); Smith et al. (1996)
Endrin	**2.22**	na	207	**62.4**	MacDonald et al. (2000); Smith et al. (1996)
Lindane (gamma-BHC)	2.37	**0.94**	4.99	**1.38**	Smith et al. (1996)
Heptachlor epoxide	2.47	**0.6**	16	**2.74**	Smith et al. (1996)

[a] TECs and PECs reported by MacDonald et al. (2000).

[b] TELs and PELs reported by Smith et al. (1996).

BHC – benzene hexachloride
COI – contaminant of interest
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
na – not available
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PEC – probable effects concentration
PEL – probable effects level
SSL – soil screening level
SVOC – semivolatile organic compound
TEC – threshold effects concentration
TEL – threshold effects level

Bold indicates selected soil thresholds (i.e., the lower of the TEC and TEL and the lower of the PEC and PEL).

Table 2. Summary of Surface Water Thresholds

Water COI	Water Threshold		Source
	Chronic	Acute	
Metals (µg/L)			
Arsenic (dissolved)	150	340	EPA AWQC (EPA 2009)
Barium (total)	4	110	Tier II (Suter and Tsao 1996)
Copper (dissolved)	1.3[a]	1.6[a]	EPA AWQC (EPA 2009)
VOCs (µg/L)			
Acetone	1,500	28,000	Tier II (Suter and Tsao 1996)

[a] AWQC values were hardness-adjusted based on the average Force Lake hardness (10.7 mg/L $CaCO_3$).

AWQC – ambient water quality criteria
COI – contaminant of interest
EPA – US Environmental Protection Agency
VOC – volatile organic compound

Table 3. Summary of Terrestrial Invertebrate Soil Thresholds

Soil COI	Soil Threshold Source			Source of Selected Soil Threshold
	EPA Eco-SSL[a]	ORNL[b]	DEQ 2001[c]	
Metals (mg/kg dw)				
Aluminum	na	na	**600**	DEQ (2001)
Antimony	**78**	na	na	Ecological-SSL (EPA 2005a)
Arsenic	na	**60**	**60**	DEQ (2001); Efroymson et al. (1997)
Barium	**330**	na	3,000	Ecological-SSL (EPA 2005b)
Beryllium	**40**	na	na	Ecological -SSL (EPA 2005c)
Cadmium	140	**20**	**20**	DEQ (2001); Efroymson et al. (1997)
Chromium	na	**0.4**[d]	**0.4**[d]	DEQ (2001); Efroymson et al. (1997)
Cobalt	na	na	**1,000**	DEQ (2001)
Copper	80	**50**	**50**	DEQ (2001); Efroymson et al. (1997)
Lead	1,700	**500**	**500**	DEQ (2001); Efroymson et al. (1997)
Manganese	450	na	**100**	DEQ (2001)
Mercury	na	**0.1**[e]	**0.1**[e]	DEQ (2001); Efroymson et al. (1997)
Nickel	280	**200**	**200**	DEQ (2001); Efroymson et al. (1997)
Selenium	**4.1**	70	70	Ecological-SSL (EPA 2007c)
Silver	na	na	**50**	DEQ (2001)
Zinc	**120**	200	200	Ecological-SSL (EPA 2007d)
PAHs (µg/kg dw)				
Total LPAHs	**29,000**	na	na	Ecological-SSL (EPA 2007b)
Total HPAHs	**18,000**	na	na	Ecological-SSL (EPA 2007b)
Other SVOCs (µg/kg dw)				
1,4-Dichlorobenzene	na	**20,000**	**20,000**	DEQ (2001); Efroymson et al. (1997)
Hexachlorobenzene	na	na	**1,000,000**	DEQ (2001)
Pentachlorophenol	31,000	6,000	**4,000**	DEQ (2001)

Table 3. Summary of Terrestrial Invertebrate Soil Thresholds

Soil COI	Soil Threshold Source			Source of Selected Soil Threshold
	EPA Eco-SSL[a]	ORNL[b]	DEQ 2001[c]	
Phenol	na	**30,000**	**30,000**	DEQ (2001); Efroymson et al. (1997)

[a] Based on EPA Ecological SSL for soil invertebrates (EPA 2007a).

[b] Based on ORNL soil thresholds for earthworms (Efroymson et al 1997).

[c] Based on DEQ soil thresholds for invertebrates (DEQ 2001).

[d] The soil TRV for chromium (0.4 mg/kg dw) as reported in DEQ (2001) and Efroymson et al. (1997) was determined from the LOEC of 2 mg/kg dw using a safety factor of 5. Per consultation with EPA, safety factor-adjusted TRVs are not recommended for use in the Harbor Oil baseline ERA; therefore the non-adjusted LOEC of 2 mg/kg dw was selected for evaluation in the baseline ERA.

[e] The soil TRV for mercury (0.1 mg/kg dw) as reported in DEQ (2001) and Efroymson et al. (1997) was determined from the LOEC of 0.5 mg/kg dw using a safety factor of 5. Per consultation with EPA, safety factor-adjusted TRVs are not recommended for use in the Harbor Oil baseline ERA; therefore the non-adjusted LOEC of 0.5 mg/kg dw was selected for evaluation in the baseline ERA.

COI – contaminant of interest
DEQ – Oregon Department of Environmental Quality
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
HPAH - high-molecular-weight polycyclic aromatic hydrocarbon
LPAH - low-molecular-weight polycyclic aromatic hydrocarbon
na – not available
ORNL – Oak Ridge National Laboratory
PAH – polycyclic aromatic hydrocarbon
SSL – soil screening level
SVOC – semivolatile organic compound

Bold indicates selected soil threshold.

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Mercury	mercuric chloride	guppy	200	nv	sediment and water	20 days	survival	no effect on survival	Kudo and Mortimer (1979)
Mercury	methylmercury	golden shiner	**230**	nv	food	90 days	survival	predator avoidance	Webber and Haines (2003)
Mercury	methyl-mercuric chloride	mummichog	200	**470**	water	42 days	survival	male survival	Matta et al. (2001)
Mercury	mercuric chloride	fathead minnow	0.8	1,310	food	60 days	growth	body weight	Snarski and Olson (1982)
Mercury	methyl-mercuric chloride	rainbow trout (fingerling)	2,280	nv	water	24 days	growth	body weight	Phillips and Buhler (1978)
Mercury	methylmercury	brook trout	2,700	3,400	water	756 days	reproduction	reduced number of viable eggs produced	McKim et al. (1976)
Mercury	mercuric chloride	fathead minnow	2,750	4,180	water	60 days	survival	mortality	Snarski and Olson (1982)
Mercury	mercuric chloride	fathead minnow	2,840	4,470	water	287 days	reproduction	reproduction	Snarski and Olson (1982)
Mercury	methylmercury	rainbow trout (juvenile)	5,000	nv	water	84 days	growth, survival	no effect on growth or survival	Lock (1975)
Mercury	methylmercury	goldfish	nv	5,600	water	2 days	survival	mortality	Heisinger et al. (1979)
Mercury	methyl-mercuric chloride	rainbow trout (fingerling)	5,670	nv	water	24 days	growth	no effect on growth	Phillips and Buhler (1978)
Mercury	methyl-mercuric chloride	bluegill (juvenile)	nv	6,500	water	12.5 days	survival	mortality	Cember et al. 1978
Mercury	methyl-mercuric chloride	rainbow trout (fingerling)	8,630	nv	water	24 days	growth	no effect on growth	Phillips and Buhler (1978)
Mercury	unspecified	brook trout	9,400	nv	water	756 days	growth, survival	reduced juvenile weight	McKim et al. (1976)
Mercury	methylmercury	rainbow trout (fingerling)	nv	10,000	food	84 days	growth	reduced growth and final body weight (after 84 days)	Rodgers and Beamish (1982)
Mercury	methylmercury	fathead minnow	10,900	nv	water	336 days	growth, survival	no effect on growth or survival	Olson et al. (1975)
Mercury	methyl-mercuric chloride	mummichog	1,100	11,000	food	42 days	reproduction	F1 fertilization success	Matta et al. (2001)

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Mercury	methyl-mercuric chloride	rainbow trout	12,000	nv	water	75 days	growth, survival	body weight	Niimi and Lowe-Jinde (1984)
Mercury	methyl-mercuric chloride	mummichog	12,000	nv	food	42 days	reproduction	F1 hatchability, survival, fecundity, F2 larval survival	Matta et al. (2001)
Mercury	methyl-mercuric chloride	mummichog	12,000	nv	food	42 days	reproduction	fecundity, fertilization success, offspring weight, female survival	Matta et al. (2001)
Mercury	unspecified	rainbow trout (fingerling)	29,000	nv		84 days	survival	no effect on survival	Rodgers and Beamish (1982)
Total PCBs	Aroclor 1260	common barbel	**104**[a]	**520**	maternal exposure	50 days	reproduction	reduced fecundity	Hugla and Thome (1999)
Total PCBs	Aroclor 1254	juvenile Chinook salmon	980	nv	food	4 weeks	growth, survival	no effect on growth or survival	Powell et al. (2003)
Total PCBs	Aroclor 1260	common barbel	520	2,640	maternal exposure	75 days	reproduction	lack of spawning in first reproductive season; egg and larval mortality	Hugla and Thome (1999)
Total PCBs	Aroclor 1254	rainbow trout	8,000	nv	food	32 weeks	growth, survival	no effect on growth or survival	Lieb et al. (1974)
Total PCBs	Aroclor 1254	sheepshead minnow	1,900	9,300	maternal exposure water	28 days	reproduction	decreased fry survival in the first week after hatch	Hansen et al. (1974a)
Total PCBs	Aroclor 1254	pinfish	nv	14,000	water	20 days	survival	reduced survival	Hansen et al. (1971)
Total PCBs	Aroclor 1242	channel catfish	nv	14,300	food	20 weeks	growth	40% reduction in body weight gain	Hansen et al. (1976)
Total PCBs	Aroclor 1268	mummichog	15,000	nv	food	6 weeks	reproduction, survival	no effect on fertilization, hatching, or larval survival	Matta et al. (2001)
Total PCBs	Clophen A50	*Phoxinus phoxinus* (minnow)	nv	25,000	food	45 days; observation for 355 additional days	reproduction	increased fry mortality; delayed spawning	Bengtsson (1980)

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Total PCBs	Aroclor 1254	spot	27,000	46,000	water	20 days	survival	reduced survival	Hansen et al. (1971)
Total PCBs	Aroclor 1248, 1260 mixture	fathead minnow	25,000	50,000	water	30 days	growth	reduced weight of second-generation fish at 30 days	DeFoe et al. (1978)
Total PCBs	Aroclor 1254	brook trout (embryos)	31,000	71,000	water	128 days (10 days prior to hatch and 118 days after)	growth	reduced fry growth	Mauck et al. (1978)
Total PCBs	Aroclor 1016	sheepshead minnow	110,000	nv	water	4 weeks	reproduction	no effect on fertilization success, survival of embryos, or fry survival	Hansen et al. (1975)
Total PCBs	Aroclor 1016	pinfish	nv	106,000	water	33 days	survival	50% mortality	Hansen et al. (1974b)
Total PCBs	Aroclor 1254: 1260 mixture	rainbow trout (juvenile)	120,000	nv	water	90 days	survival	no effect on survival	Mayer et al. (1985)
Total PCBs	Aroclor 1254: 1260 mixture	rainbow trout (juvenile)	70,000	120,000	water	90 days	growth	reduced growth	Mayer et al. (1985)
Total PCBs	Aroclor 1254	brook trout (embryos)	71,000	125,000	water	128 days (10 days prior to hatch and 118 days after)	survival	reduced fry survival	Mauck et al. (1978)
Total PCBs	Aroclor 1016	sheepshead minnow (fry)	57,000	200,000	water	4 weeks	survival	reduced fry survival	Hansen et al. (1975)
Total PCBs	Clophen A50	goldfish	nv	250,000	water	21 days	survival	reduced survival	Hattula and Karlog (1972)
Total PCBs	Aroclor 1254	fathead minnow	nv	429,000 (female)	water	8 months	reproduction	reduced spawning	Nebeker et al. (1974)
Total PCBs	Aroclor 1242, 1254, or 1260	fathead minnow	nv	1,860 – 749,000	water	100 to 300 hours		range of lethal body burdens (concentration associated with mortality of individuals)	van Wezel et al. (1995)
Total DDTs	DDT mixture	golden shiner	25	nv	food	6-15 days	survival	no effect on survival	Courtney and Reed (1971)

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Total DDTs	DDT mixture	cutthroat trout	**1,800**	**1,800**	water	612 days (mortality observed at 111 days)	survival	mortality	Allison et al. (1964)
Total DDTs	Total DDT	brook trout (juvenile)	1,920	nv	food	120 days	survival	no effect on survival	Macek and Korn (1970)
Total DDTs	Total DDT	cutthroat trout	1,200	2,000	water	20 mo (mortality observed at 4 mo)	survival	survival	Allison et al. (1963)
Total DDTs	Total DDT	brook trout	nv	2,800 - 3,000	food	156 days	reproduction	offspring (sac-fry and embryo) mortality	Macek (1968b)
Total DDTs	Total DDT	chinook salmon	620	3,650	food	40 days	survival		Buhler et al. (1969)
Total DDTs	Total DDT	rainbow trout	4,670	nv	food	140 days	growth, survival	survival, growth	Macek et al. (1970)
Total DDTs	Total DDT	killifish	nv	5,200	water	24 hrs	survival	25% mortality at 24 hrs	Crawford and Guarino (1976)
Total DDTs	DDT mixture	cutthroat trout	3,900	5,500	food	612 days	survival	survival	Allison et al. (1964)
Total DDTs	DDT mixture	pinfish	nv	5,600	food	21 days	survival	35% mortality at 21 days	Butler (1969)
Total DDTs	DDT mixture	pinfish	nv	7,890	food	2 days	survival	63.5% mortality	Butler (1969)
Total DDTs	Total DDT	brook trout (fry)	7,600	nv	food	156 days	growth, survival	survival, growth	Macek (1968b)
Total DDTs	Total DDT	brook trout	11,200	nv	food	31 wks	growth	increased growth	Macek (1968a)
Total DDTs	Total DDT	chinook salmon	11,400	12,100	food	40 days	survival	survival	Buhler et al. (1969)
Total DDTs	Total DDT	brook trout	nv	20,200 - 45,800	food	26 wks	survival	reduced survival during stress (starvation)	Macek (1968a)
Total DDTs	Total DDT	green sunfish/ pumpkin-seed	nv	24,000	water	90 days	survival	survival	Hamelink et al. (1971)
Total DDTs	DDT mixture	Atlantic menhaden	24,000	nv	food	48 (109)[a]	growth	growth	Warlen et al. (1977)
Total DDTs	Total DDT	mosquito fish	nv	26,500	water	16 days	survival	survival	Pillai et al. (1977)
Total DDTs	Total DDT	fathead minnow	40,000	nv	food and water	266 days	survival	survival	Jarvinen et al. (1976, 1977)

Table 4. Summary of Acceptable Toxicity Studies for the Selection of Fish Tissue-Residue TRVs

Chemical	Chemical Form	Test Species	NOAEL (µg/kg ww)	LOAEL (µg/kg ww)	Exposure Mode	Exposure Duration	Endpoint	Endpoint Effect	Source
Total DDTs	Total DDT	sailfin molly	51,400	92,700	water	21 days	growth, survival	survival, growth	Benton et al. (1994)
Total DDTs	Total DDT	coho salmon	16,600	69,600	food	60 days	survival	survival	Buhler et al. (1969)
Total DDTs	Total DDT	goldfish	130,000	200,000	food and water	38 to 58 days	survival	survival	Rhead and Perkins (1984)

[a] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

DDT – dichlorodiphenyltrichloroethane
LOAEL – lowest-observed-effect concentration
NOAEL – no-observed-effect concentration
nv – no value
PCB – polychlorinated biphenyl
TRV – toxicity reference value
ww – wet weight

BOLD represents selected NOAEL and LOAEL TRVs.

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	nv	**0.50**	food (prepared diet)	24 days	growth	body weight	Cockell et al. (1991)
Arsenic	sodium arsenite	rainbow trout (juvenile)	**0.40**	0.60	food (prepared diet)	8 weeks	growth	body weight	Oladimeji et al. (1984)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	0.12	0.62	food (prepared diet)	16 days	growth	body weight	Cockell et al. (1991)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	0.63	nv	food (prepared diet)	24 days	growth	body weight	Cockell et al. (1991)
Arsenic	disodium arsenate	rainbow trout (juvenile)	nv	1.0	food (prepared diet)	4 weeks	growth	body weight	Cockell and Bettger (1993)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	0.55	1.0	food (prepared diet)	12 weeks	growth	body weight	Cockell et al. (1992)
Arsenic	disodium arsenate heptahydrate	rainbow trout (juvenile)	nv	1.4	food (prepared diet)	8 weeks	growth	body weight	Cockell et al. (1992)
Arsenic	arsenic trioxide	rainbow trout (juvenile)	nv	1.7	food (prepared diet)	8 weeks	growth	body weight	Cockell and Hilton (1988)
Arsenic	disodium arsenate heptahydrate	striped bass (juvenile)	0.52	1.9	food (prepared diet)	6 weeks	growth	body weight	Blazer et al. (1997)
Arsenic	disodium arsenate	rainbow trout (juvenile)	nv	2.9	food (prepared diet)	8 weeks	growth	body weight	Cockell and Hilton (1988)
Cadmium	cadmium nitrate	rockfish (juvenile)	**0.0020**[b,c]	**0.010**[c]	food (prepared diet)	60 days	growth	reduced body weight and length, growth rate, and condition factor	Kim et al. (2004); Kang et al. (2005)
Cadmium	cadmium chloride	guppy (adult)	1.2	nv	food (midge larvae)	2 months	reproduction	no effect on number of live fry, fry survival, or premature release of embryos	Hatakeyama and Yasuno (1987)
Cadmium	cadmium chloride	guppy (60 days old)	1.6	nv	food (midge larvae)	30 days	growth	no effect on body weight	Hatakeyama and Yasuno (1987)
Cadmium	cadmium nitrate	rockfish	2.5	nv	food (prepared diet)	60 days	survival	no effect on survival	Kim et al. (2004)
Cadmium	cadmium chloride	guppy (30 days old)	**3.2**[d]	**4.6**[d]	food (midge larvae)	7 months	reproduction	reduced cumulative number of fry produced	Hatakeyama and Yasuno (1987)
Cadmium	cadmium chloride	rainbow trout	4.1	nv	food (brine shrimp) and water	60 days	survival	no effect on survival	Mount et al. (1994)

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Cadmium	cadmium nitrate	rainbow trout	5.9	nv	food (prepared diet)	15 to 30 days	survival, growth	no effect on specific growth rate, survival	Baldisserotto et al. (2005)
Cadmium	cadmium chloride	guppy	1.0	nv	food (M*oina macrocoipa*)	10 to 30 days	growth	no effect on growth	Hatakeyama and Yasuno (1982)
Cadmium	cadmium nitrate	rainbow trout	9.4	nv	food (prepared diet)	28 days	survival, growth	no effect on growth rate or survival	Franklin et al. (2005)
Cadmium	cadmium chloride	guppy (30 days old)	nv	9.4	food (midge larvae)	7 months	survival, growth	reduced female growth and survival	Hatakeyama and Yasuno (1987)
Cadmium	cadmium nitrate	rainbow trout (juvenile)	16	28	food (prepared diet)	36 days	survival	reduced survival	Szebedinsky et al. (2001)
Cadmium	cadmium sulfate	rainbow trout (juvenile)	nv	68	food (prepared diet)	28 days	survival	reduced survival	Handy (1992)
Chromium	chromium (III)	grey mullet	**9.42**	nv	food and sediment	8 weeks	growth	body weight	Walsh et al. (1994)
Copper	copper sulfate	channel catfish (fingerling)	0.24	0.48	food (prepared diet)	16 weeks	growth	reduced growth	Murai et al. (1981)
Copper	copper sulfate	rockfish (juvenile)	**1.0**	**2.0**	food (prepared diet)	60 days	growth	reduced growth rate	Kang et al. (2005)
Copper	copper sulphate	rainbow trout	2.2	nv	food (prepared diet)	32 days	survival	no effect on survival	Handy (1992)
Copper	copper sulphate pentahydrate	rainbow trout	6.8	nv	food (prepared diet)	16 weeks	growth	no effect on growth	Lanno et al. (1985b)
Copper	copper sulfate	rainbow trout	13	nv	food (prepared diet)	42 days	growth	no effect on growth	Miller et al. (1993)
Copper	copper sulphate pentahydrate	Atlantic salmon (parr)	17	nv	food (prepared diet)	4 weeks	growth	no effect on body weight, length, or condition factor	Berntssen et al. (1999b)
Copper	copper sulphate pentahydrate	rainbow trout	17	nv	food (prepared diet)	24 weeks	survival, growth	no effect on growth or survival	Lanno et al. (1985b)
Copper	copper sulphate pentahydrate	rainbow trout	18	nv	food (prepared diet)	8 weeks	survival	no effect on survival	Lanno et al. (1985b)

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Copper	copper sulphate pentahydrate	rainbow trout	nv	18	food (prepared diet)	8 weeks	growth	reduced growth	Lanno et al. (1985b)
Copper	copper sulphate pentahydrate	rainbow trout	nv	20	food (prepared diet) and water	16 weeks	growth	reduced growth	Lanno et al. (1985a)
Copper	copper sulfate pentahydrate	Atlantic salmon (fry)	14	20	food (prepared diet)	3 months	growth	reduced growth	Lundebye et al. (1999)
Copper	copper sulphate	Atlantic salmon	20	28	food (prepared diet)	3 months	growth	reduced growth	Berntssen et al. (1999a)
Copper	copper sulphate pentahydrate	rainbow trout	42	nv	food (prepared diet)	28 days	survival, growth	no effect on growth or survival	Kamunde et al. (2001)
Copper	copper chloride	rainbow trout (fry)	26	50	food (brine shrimp) and water	60 days	survival	reduced survival	Mount et al. (1994)
Copper	copper chloride	rainbow trout (fry)	60	nv	food (brine shrimp) and water	60 days	growth	no effect on body weight and length	Mount et al. (1994)
Copper	copper sulphate pentahydrate	grey mullet	nv	60	food (prepared diet)	67 days	growth	reduced growth	Baker et al. (1998)
Copper	copper sulphate	rainbow trout	69	nv	food (prepared diet)	28 days	survival	no effect on survival	Handy (1993)
Lead	lead nitrate	rainbow trout	12.6	nv	food (brine shrimp)	60 days	survival, growth	no effect on body weight and length; 100% survival	Mount et al. (1994)
Lead	unspecified	rainbow trout	**134**	nv	food (prepared diet)	191 days	growth	no effect on growth	Goettl et al. (1976)
Silver	silver sulfide	rainbow trout	**70**	nv	food (prepared diet)	58 days	growth	reduced body weight	Galvez and Wood (1999)
Vanadium	sodium orthovanadate	rainbow trout (juvenile)	**0.039**[e]	**0.19**	food (prepared diet)	12 weeks	growth	reduced body weight	Hilton and Bettger (1988)
Zinc	unspecified	rainbow trout	**19**	**38**	food (prepared diet)	6 weeks	growth	reduced growth	Takeda and Shimma (1977)

Table 5. Summary of Acceptable Toxicity Studies for the Selection of Fish Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Zinc	zinc chloride	rainbow trout	114	nv	food (brine shrimp)	60 days	survival, growth	no effect on body weight and length; 97% survival	Mount et al. (1994)
Benzo(a)pyrene	benzo(a)pyrene	English sole (juvenile)	**0.66**	**1.4**	food (worms)	10 to 12 days	growth	reduced daily growth rate	Rice et al. (2000)
Benzo(a)pyrene	benzo(a)pyrene	rainbow trout (juvenile)	nv	3.7	food (prepared diet)	53 days	survival, growth	reduced body weight; no effect on survival	Hendricks et al. (1985)
Benzo(a)pyrene	benzo(a)pyrene	rainbow trout (juvenile)	1.9	19	food (prepared diet)	18 months	growth	reduced body weight	Hart and Heddle (1991)
Benzo(a)pyrene	benzo(a)pyrene	grouper	13	nv	food (prepared diet)	4 weeks	survival, growth	no effect on survival or growth (body weight and total length)	Wu et al. (2003)
Total PAHs	PAH mixture	English sole	nv	0.12	food (worms contaminated with field sediment)	10-12 days	growth	reduced daily growth rate	Rice et al. (2000)
Total PAHs	PAH mixture	Chinook salmon (juvenile)	5.0	nv	food (prepared diet)	7 weeks	survival, growth	no effect on body weight, length, or condition factor	Palm et al. (2003)
Total PAHs	PAH mixture	Chinook salmon (juvenile)	5.0	nv	food (prepared diet)	4 weeks[c]	survival	no impact to disease resistance	Palm et al. (2003)
Total PAHs	PAH mixture	Chinook salmon (juvenile)	**6.1**	**18**	food (prepared diet)	53 days	growth	reduced body weight (as dry body weight)	Meador et al. (2006)

[a] NOAEL and LOAEL TRVs, expressed as a dietary dose (mg/kg bw/day), were calculated from literature studies based on body weight, ingestion rate, and dietary concentrations.

[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

[c] Selected NOAEL and LOAEL for the screening-level risk assessment.

[d] Selected NOAEL and LOAEL for the baseline risk evaluation.

[e] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

bw – body weight
LOAEL – lowest-observed-effect concentration
nv – no value
NOAEL – no-observed-effect concentration
PAH – polycyclic aromatic hydrocarbon
TRV – toxicity reference value

BOLD identifies the selected NOAEL and LOAEL TRVs.

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Metals									
Aluminum	aluminum citrate	Japanese quail	90	nv	food	65 days and through reproduction	reproduction, growth	body weight	Wolff and Phillips (1990)
Aluminum	aluminum sulfate	ring dove	**157**	nv	food	4 months	reproduction, growth	adult growth, fertility, hatchability, egg permeability	Carriere et al. (1986)
Arsenic	sodium arsenate	mallard	6.1	nv	food	10 weeks	growth, survival	female	Camardese et al. (1990)
Arsenic	sodium arsenate	mallard	**10**	**40**	food	115-128 days	reproduction	delayed egg laying; depressed egg weight and shell thinning; decrease offspring body weight and production	Stanley et al. (1994)
Arsenic	sodium arsenite	mallard - young	25	50	food	154 days	survival	survival	USFWS (1964)
Cadmium	cadmium chloride	mallard young (females)	**1.5**	nv	food	12 weeks	growth	body weight	Cain et al. (1983)
Cadmium	cadmium sulfate	leghorn hen	0.73	2.9	food	48 weeks	reproduction	egg production, shell thickness	Leach et al. (1979)
Cadmium	cadmium chloride	Japanese quail (chicks)	nv	**4.0**	food	6 weeks	growth	male body weight	Richardson et al. (1974)
Cadmium	cadmium chloride	mallard	19	nv	food	90 days	survival	no effect on survival	White and Finley (1978a)
Cadmium	cadmium chloride	mallard	20	nv	food	30-90 days	survival, growth	body weight, adult survival	White and Finley (1978b)
Cadmium	cadmium chloride	mallard	1.5	20	food	30-90 days	reproduction	egg production	White and Finley (1978b)
Cadmium	cadmium chloride	leghorn chicks	nv	24	food	21 days	growth	male body weight	Freeland and Cousins (1973)
Cadmium	cadmium chloride	leghorn chicks	nv	40	food	20 days	growth	male body weight	Pritzl et al. (1974)
Cadmium	cadmium chloride	mallard	16	47	food	42 days	growth	body weight	DiGiulio and Scanlon (1984)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Chromium	copper sulfate	white leghorn layers (hens)	0.10	nv	food	28 days	reproduction	egg weight and shell thickness	Lien et al. (2004)
Chromium	chromium potassium sulfate	black duck	**1.0**	**5.0**	food	10 months (and critical lifestage)	reproduction	duckling survival	Haseltine et al. (unpublished)
Chromium	sodium chromate	Nochols chicks	7.7	nv	food	22 days	growth, survival	male adult survival, male body weight	Romoser et al. (1961)
Cobalt	cobalt chloride	broiler chicks	**2.31**[b]	**23.1**	food	14 days	growth	body weight, survival	Diaz et al. (1994)
Copper	copper sulfate, copper amino acid complex	broiler chicks	2.1	nv	food	17 days	growth, survival	body weight, survival	Dozier et al. (2003)
Copper	copper sulfate (hydrous)	hisex-brown hens	11.2	nv	food	90 days	reproduction, survival	damaged egg ratio, egg weight and survival	Balevi & Coskun (2004)
Copper	copper sulfate	chicks, day-old	16	**29**	food	25 days	growth	growth	Smith (1969)
Copper	copper sulfate	chicks	**21**	41	food	4 weeks	growth	growth and gizzard erosion	Poupoulis and Jensen (1976)
Copper	copper chloride	chicks	nv	66	food	8-22 days	growth	body weight	Persia et al. (2004)
Copper	copper oxide	chicks	47	62	food	10 weeks	growth/ survival	growth, survival	Mehring et al. (1960)
Copper	copper sulfate	white leghorn layers (hens)	15	nv	food	28 days	reproduction	egg weight and shell thickness	Lien et al. (2004)
Lead	lead nitrate	mallards, first-year	2.5	nv	food	12 weeks	survival	survival	Finley et al. (1976)
Lead	metallic lead powder	American kestrel	**5.82**	nv	food	5-7 months	survival/ reproduction	survival, fertility, egg production, eggshell thinning	Pattee (1984)
Lead	lead acetate	Japanese quail	2.0	**20**	food	12 weeks	reproduction	egg hatchability	Edens et al. (1976)
Lead	lead acetate	Japanese quail (chicks)	5.5	28	food	6 weeks	growth	body weight	Morgan et al. (1975)
Mercury	methylmercury chloride	great egret, one day old	**0.018**[c]	**0.091**	food	14 weeks	growth	growth	Spalding et al. (2000)
Mercury	methylmercury chloride	mallard	0.50	nv	food	>60 days	reproduction	eggshell thickness	Heinz (1980)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Mercury	methylmercury chloride	Japanese quail (chicks at hatching)	nv	0.9	food	5 days	survival	hatchling survival (16%)	Hill and Soares (1987)
Mercury	methylmercury chloride	zebra finch	0.72	1.4	food	76 days	survival	survival	Scheuhammer (1988)
Mercury	methylmercury chloride	northern bobwhite, 12 day old	0.43	1.6	food	6 weeks	survival	survival	Spann et al. (1986)
Mercury	mercuric chloride	Japanese quail, one day old	0.80	1.6	food	10 weeks	reproduction	eggshell thickness	Stoewsand et al. (1971)
Mercury	dimethyl mercury	American kestrel	5.24	nv	food	3 months	survival	eggshell thickness	Peakall and Lincer (1972)
Mercury	mercuric chloride	Japanese quail (chicks at hatching)	nv	62	food	5 days	survival	hatchling survival (12%)	Hill and Soares (1987)
Nickel	nickel sulfate	broiler chicks	15	nv	food	4 weeks	growth	body weight gain	Weber and Reid (1968)
Nickel	nickel sulfate	broiler chicks	nv	33	food	4 weeks	growth	reduced body weight	Weber and Reid (1968)
Nickel	nickel acetate	broiler chicks	17	nv	food	4 weeks	growth	body weight gain	Weber and Reid (1968)
Nickel	nickel acetate	broiler chicks	nv	38	food	4 weeks	growth	reduced body weight	Weber and Reid (1968)
Nickel	nickel sulfate	mallard	**77**	**107**	food	90 days	survival, growth	survival, body weight	Cain and Pafford (1981)
Nickel	nickel sulfate	mallard	132	nv	food	90 days	survival, growth, reproduction	adult survival; body weight; hatchling weight	Eastin and O'Shea (1981)
Selenium	sodium selenite, sel-plex 50	broiler chicks	0.025	nv	food	~40 days	growth, survival	body weight	Choct et al. (2004)
Selenium	seleno-methionine	mallard	0.42	**0.82**	food	~100 days	reproduction	offspring growth/survival	Heinz et al. (1989)
Selenium	sodium selenite Na_2SeO_3	mallard	**0.50**	1.0	food	4 weeks before laying to 3 wks after hatching	reproduction	embryo abnormalities	Heinz et al. (1987)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Selenium	sodium selenite	mallard	1.0	2.5	food	4 weeks before laying to 3 wks after hatching	growth	adult growth	Heinz et al. (1987)
Selenium	seleno-methionine	mallard	1.6	nv	food	~100 days	survival, growth	body weight; adult survival	Heinz et al. (1989)
Selenium	seleno-methionine	screech owl	1.0	3.2	food	~ 3 months	growth, reproduction	body weight, hatching success, 5 days survival, clutch size, egg size and mass	Wiemeyer and Hoffman (1996)
Selenium	sodium selenite	mallard	4.6	10	food	42 days	survival		Heinz et al. (1988)
Selenium	sodium selenite	mallard	2.1	4.6	food	42 days	growth	body weight	Heinz et al. (1988)
Selenium	sodium selenite	mallard	2.5	10	food	4 weeks before laying to 3 wks after hatching	survival	adult survival	Heinz et al. (1987)
Vanadium	ammonium metavanadate	white leghorn hens	**1.2**	**2.3**	food	4 weeks	growth	body weight	Ousterhout and Berg (1981)
Vanadium	vanadium sulfate	mallard	11.4	nv	food	12 weeks	growth, survival	body weight, survival	White and Dieter (1978)
Zinc	copper sulfate, copper amino acid complex	broiler chicks	17	nv	food	17 days	growth, survival	body weight, survival	Dozier et al. (2003)
Zinc	zinc oxide, zinc sulfate, or zinc carbonate	white rock chicks	**82**	**124**	food	5 weeks	growth	growth	Roberson and Schaible (1960)
Zinc	zinc sulfate	white leghorn hens	133	nv	food and supplements	44 weeks	reproduction	egg hatchability	Stahl et al. (1990)
Zinc	zinc carbonate	mallard (7 wks old)	nv	300	food	60 days	survival	survival, leg paralysis	Gasaway and Buss (1972)
Zinc	zinc acetate	Hubbard broiler chicks	330	659	food	5 weeks	growth/ survival	survival, reduced growth	Oh et al. (1979)
Zinc	zinc chloride	chicks	nv	344	food	8-22 days	growth	body weight	Persia et al. (2004)
PAHs									
Benzo(a)pyrene	benzo(a)pyrene	pigeons	**0.28[c]**	**1.4**	weekly intramuscular injection	5 months	reproduction	fertility, ovarian appearance	Hough et al. (1993)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Benzo(a)pyrene	benzo(a)pyrene	white rock chicken	33	nv	food	30 days	growth	body weight gain	Rigdon and Neal (1963)
Total PAHs	aromatic hydrocarbon mixture including individual PAHs	mallard	**8**	**40**	food	7 months	growth	little change in body weight	Patton and Dieter (1980)
Total PAHs	petroleum hydrocarbon mixture including PAHs)	mallard	400	nv	food	7 months	survival	survival	Patton and Dieter (1980)
Phthalates									
BEHP	BEHP	ringed turtle-dove	1.45	nv	food	4 weeks	reproduction	eggshell thickness	Peakall (1974)
BEHP	BEHP	European starling	67.8	nv	food	30 days	growth	growth, food consumption	O'Shea and Stafford (1980)
BEHP	BEHP	chicken	**65.8**[c]	**329**	food	230 days	reproduction	cessation of egg laying, abnormal ovaries	Ishida et al. (1982)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	**1.1**	nv	food	90 days	reproduction, survival	hatchability, survival	Vos et al. (1971)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	1.2	nv	food	90 days	growth	body weight	Schwetz et al. (1974)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	nv	**1.2**	food	90 days	reproduction	chicks hatched and survival	Schwetz et al. (1974)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	nv	4.5	food	90 days	reproduction	hatchability	Vos et al. (1971)
Hexachlorobenzene	hexachloro-benzene	Japanese quail	nv	5	food	90 days	survival	no effect on survival	Vos et al. (1971)
Pentachlorophenol	pentachloro-phenol	chicks	**22**	**63**	food	8 weeks	growth	body weight	Prescott et al. (1982)
PCBs									
Total PCBs	Aroclor 1248	American kestrel	nv	0.35	food	5.5 months	reproduction	eggshell weight and thickness	Lowe and Stendell (1991)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
Total PCBs	Aroclor 1248	screech owl	**0.49**	nv	food	2 generations	reproduction	eggshell thickness, egg production, hatching success, fledging success	McLane and Hughes (1980)
Total PCBs	Aroclor 1242	Japanese quail	nv	0.60	food	45 days	reproduction	eggshell thinning	Hill et al. (1976)
Total PCBs	Aroclor 1254	ringed turtle-dove	nv	**1.4**	food	2 generations	reproduction	hatching success in second generation	Peakall et al. (1972); Peakall and Peakall (1973)
Total PCBs	Aroclor 1254	mallard	2.5	nv	food	~ 1 month	reproduction	Reproductive success	Custer and Heinz (1980)
Total PCBs	Aroclor 1254	mallard	3.9	nv	food	4 months	reproduction	egg production, eggshell thinning	Risebrough and Anderson (1975)
Total PCBs	1:1:1 ratio of Aroclor 1248:1254:1260	American kestrel	nv	5 to 7	food	100 days until eggs hatched	reproduction	egg laying in second generation (exposed in ovo); also some effect on clutch size and fledgling success	Fernie et al. (2000; 2001)
Total PCBs	1:1:1 ratio of Aroclor 1248:1254:1260	American kestrel	nv	5 to 7	food	1 mo prior to pairing until anticipated egg hatching	reproduction	cracked eggs, embryo abnormalities;	Fernie et al. (2003b)
Total PCBs	1:1:1 ratio of Aroclor 1248:1254:1260	American kestrel	nv	7	food	100 days	reproduction	offspring survival and offspring body weight	Fernie et al. (2003a)
Total PCBs	Aroclor 1242	mallard	nv	15	food	12 weeks	reproduction	hatchability, embryo survival, egg viability, embryo abnormalities	Haseltine and Prouty (1980)
Pesticides									
DDTs[d]	p,p'-DDT	quail	nv	0.15	food	26 wks+12 days	reproduction	eggshell thickness	Stickel and Rhodes (1970)
DDTs[d]	p,p'-DDT	mallard	0.19	nv	food	11 months	reproduction	eggshell weight and thickness	Davison and Sell (1974)
DDTs[d]	DDE	barn owls	**0.064**[c]	**0.32**	food	2 years (2 nestings)	reproduction	eggshell breakage/ thickness; nestling survival	Mendenhall et al. (1983)

Table 6. Summary of Acceptable Toxicity Studies for the Selection of Bird Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[a] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Endpoint Effect	Source
DDTs[d]	DDE	American kestrel	nv	0.35	food	14 days	reproduction	eggshell thinning, egg permeability	Peakall et al. (1973)
DDTs[d]	technical DDD	mallard	nv	0.90	food	2 years	reproduction	hatchling survival, production	Heath et al. (1969)
DDTs[d]	p,p'-DDE	mallard	nv	0.90	food	2 years	reproduction	% cracked, hatchling survival/production, shell thickness, embryonation	Heath et al. (1969)
DDTs[d]	p,p-DDE	black duck	nv	1.0	food	7 months	reproduction	shell thickness, egg weight, hatchability, duckling survival	Longcore and Samson (1973)
DDTs[d]	DDE	mallard	nv	1.0	food	30 days	reproduction	eggshell thinning	Kolaja (1977)
DDTs[d]	DDT	mallard	nv	1.0	food	30 days	reproduction	eggshell thinning	Kolaja (1977)
DDTs[d]	p,p' DDE	American kestrel	nv	1.0	food	1 year (2 clutches)	reproduction	eggshell thickness	Wiemeyer and Porter (1970); Porter and Wiemeyer (1972)
gamma- HCH	gamma- HCH	domestic mallard	**1.6**	**3.6**	oral intubation	8 weeks	reproduction	eggshell thickness, size, quality; clutch size	Chakravarty and Lahiri (1986); Chakravarty et al. (1986)
gamma- HCH	gamma- HCH	domestic mallard	20	nv	oral intubation	8 weeks	survival, growth	survival, body weight	Chakravarty et al. (1986)
Methoxychlor	technical methoxychlor	zebra finch (chicks at 5-11 days old)	**34.6**	**346**	oral gavage	1 weeks	reproduction	number of eggs hatched, broken/missing eggs	Gee et al. (2004)
Methoxychlor	methoxychlor	zebra finch chicks	**34.6**	**346**	oral gavage	1 weeks	survival	survival	Millam et al. (2002)
Methoxychlor	technical methoxychlor	four species	831	nv	food	5 days	survival	survival	Hill et al. (1975); Heath et al. (1972)
VOCs									
Acetone	acetone	four species	**6,647**	nv	food	5 days	survival	survival	Hill et al. (1975)

[a] NOAEL and LOAEL TRVs, expressed as a dietary dose (mg/kg bw/day), were calculated from literature studies based on body weight, ingestion rate, and dietary concentrations.

[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 10.

[c] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

[d] Only the results of the nine studies with the lowest reported effects concentrations for any form of DDT are presented.

bw – body weight
LOAEL – lowest-observed-effect concentration
BEHP – bis(2-ethylhexyl)phthalate
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HCH – hexachlorocyclohexane
NOAEL – no-observed-effect concentration
nv – no value
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
VOC – volatile organic compound

BOLD represents selected NOAEL and LOAEL TRVs**.**

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Metals									
Aluminum	aluminum chloride	mouse	**34.3**	nv	food	multiple generations	reproduction	body weight, number of litters, number of offspring per litter	Ondreicka et al. (1966)
Aluminum	aluminum lactate	mouse	nv	**75.8**	food	gestation	growth	maternal and offspring body weight and length	Golub et al. (1987)
Aluminum	aluminum lactate	mouse	**137**	nv	food	8 weeks	growth	body weight and length	Golub and Keen (1999)
Antimony	antimony trioxide	rat	**1,489**	nv	food	90 days	growth, survival	body weight	Hext et al. (1999)
Arsenic	sodium arsenite	rat	**2.6**	**5.4**	food	2 years	growth	female body weight	Byron et al. (1967)
Cadmium	cadmium chloride	beagle dog	0.88	nv	food	3 months	growth	female body weight	Loeser and Lorke (1977b)
Cadmium	cadmium chloride	rat	3.0	nv	food	3 months	survival, growth	adult survival, growth	Loeser and Lorke (1977a)
Cadmium	cadmium chloride	rat	**3.5**	**13**	food	10 days (pregnancy)	growth	maternal body weight	Machemer and Lorke (1981)
Cadmium	cadmium chloride	rat	13	nv	food	10 days	survival, reproduction	adult survival; fertility, fetus weight/survival/ malformations	Machemer and Lorke (1981)
Cadmium	cadmium chloride	shrew	115	nv	food	12 weeks	growth	female body weight	Dodds-Smith et al. (1992)
Cadmium	cadmium chloride	shrew	nv	115	food	12 weeks	growth	male body weight	Dodds-Smith et al. (1992)
Cadmium	unspecified chemical form	rat	nv	189	food	12 weeks	growth, reproduction	pup birth weight; adult body weight	Pond and Walker (1975)
Chromium	chromium picolinate	rat	0.14	nv	food	12 weeks	growth	body weight and growth rate	Hasten et al. (1997)
Chromium	chromium(III) chloride/ chromium picolinate	rat	8.3	nv	food	20 weeks	growth, survival	no effect on growth, survival	Anderson et al. (1997)
Chromium	chromic oxide green	rat	1,292	nv	food	90 days	growth, reproduction	body weight, litter size, pregnancy rate, pup malformation	Ivankovic and Preussman (1975)
Chromium	chromic oxide green	rat	**1,466**	nv	food	2 years	growth, survival	body weight	Ivankovic and Preussman (1975)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Cobalt	cobalt chloride	rat	**0.1**[b]	**1.0**	diet	4 weeks	growth	body weight	Chetty et al. (1979)
Cobalt	cobalt sulfate	guinea pig	nv	1.4	diet	5 weeks	survival	no effect on survival	Mohiuddin et al. (1970)
Cobalt	cobalt sulfate	guinea pig	1.4	nv	diet	5 weeks	growth	no effect on body weight	Mohiuddin et al. (1970)
Cobalt	cobalt chloride	hooded rat	1.9	10	diet	3 days	growth	body weight	Wellman et al. (1984)
Copper	copper sulfate	mink	**18**	**26**	food	357 days	reproduction	kit survival, litter mass	Aulerich et al. (1982)
Copper	copper sulfate	mink	43	nv	food	153-657 days	growth	body weight	Aulerich et al. (1982)
Copper	copper sulfate	rat	137	nv	food	13 weeks	survival	no effect on survival	NTP (1993)
Copper	copper sulfate	rat	67	137	food	13 weeks	growth	body weight	NTP (1993)
Copper	copper sulfate	rat	93	197	food	2 weeks	growth	body weight	NTP (1993)
Copper	copper chloride	shrew	267	nv	food	weanlings for 12 weeks	survival, growth	body weight	Dodds-Smith et al. (1992)
Copper	copper sulfate	rat	305	nv	food	2 weeks	survival	no effect on survival	NTP (1993)
Copper	copper sulfate	mouse	467	nv	food	13 weeks	survival	no effect on survival	NTP (1993)
Copper	copper sulfate	mouse	227	467	food	13 weeks	growth	body weight	NTP (1993)
Copper	copper sulfate	mouse	749	nv	food	2 weeks	survival, growth	no effect on survival or growth	NTP (1993)
Lead	lead acetate	mouse	7.35	nv	food	second and third generation through puberty	reproduction	no effect on litter size	Iavicoli et al. (2006)
Lead	lead acetate	rat	**11**	**90**	food	2 years	growth	offspring weight and kidney damage	Azar et al. (1973)
Mercury	methylmercuric chloride	rat	**0.0017**[c]	**0.0084**	food	3 generations	growth	reduced growth	Verschuuren et al. (1976)
Mercury	methylmercuric chloride	rat	0.19	nv	food	3 generations	survival, reproduction	no effect on survival or reproduction	Verschuuren et al. (1976)
Mercury	methylmercuric chloride	mink	0.16	0.25	food	93 days	growth, survival	reduced growth; 40% mortality	Wobeser et al. (1976)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Mercury	methyl-mercury	mink	nv	0.64	food	2 months	growth, survival	reduced growth; 100% mortality	Aulerich et al. (1974)
Nickel	nickel chloride	rat	20	nv	food	14 days + 61 days untreated	growth	body weight	Nation et al. (1985)
Nickel	unspecified chemical form	rat	nv	**20**	food	3 generations	reproduction	increased number of stillborns in F1 generation	Ambrose et al. (1976)
Nickel	nickel sulfate	rat	**8.4**	87	food	2 years	growth	body weight	Ambrose et al. (1976)
Nickel	nickel acetate	mouse	nv	169	food	4 weeks	growth	body weight	Weber and Reid (1969)
Nickel	nickel acetate	mouse	210	313	food	weanling thru reproduction	reproduction	number of pups weaned	Weber and Reid (1969)
Nickel	nickel sulfate	rat	230	nv	food	2 years	survival	no effect on survival	Ambrose et al. (1976)
Nickel	nickel sulfate	beagle dog	2500	nv	food	2 years	survival	no effect on survival	Ambrose et al. (1976)
Selenium	sodium selenite	rat	**0.055**	**0.080**	food	6 weeks	growth	body weight	Halverson et al. (1966)
Selenium	sodium selenite	rat	0.13	0.14	food	6 weeks	survival	survival	Halverson et al. (1966)
Selenium	L-seleno-methionine	rat	nv	0.16	food	110 days	growth	body weight	Behne et al. (1992)
Selenium	selenite	rat	0.16	nv	food	110 days	growth	body weight	Behne et al. (1992)
Selenium	Na_2SeO_3, Nano-Se, or organic selenium	rat	0.17	0.28	food	13 weeks	growth	body weight	Jia et al. (2005)
Selenium	selenomethionine	hamster	0.36	0.76	food	21 days	growth	body weight	Julius et al. (1983)
Selenium	Na_2SeO_3	hamster	nv	3.4	food	21 days	growth	body weight	Julius et al. (1983)
Selenium	Na_2SeO_3	hamster	nv	5.8	food	21 days	survival	female survival	Julius et al. (1983)
Vanadium	sodium meta-vanadate	rat	**0.27**[b]	**2.7**	food	10 weeks	growth	body weight	Adachi et al. (2000)
Vanadium	sodium meta-vanadate	rat	nv	6.5	food	reproduction period	growth, reproduction	maternal body weight, offspring body weight gain and survival	Elfant and Keen (1987)
Zinc	zinc oxide	rat	**160**	**320**	food	gestation	reproduction	fetal growth, number of resorptions	Schlicker and Cox (1968)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Zinc	zinc oxide	ferret	149	433	food	2 weeks – 6 months	growth	reduced body weight	Straube et al. (1980)
Zinc	zinc carbonate	rat	400	799	food	gestation	growth	body weight	Sutton and Nelson (1937)
PAHs									
2-methylnaphthalene	2-methyl-naphthalene	mouse	**54**	**114**	food	81 weeks	growth	body weight	Murata et al. (1997)
Benzo(a)pyrene	benzo(a)pyrene	mouse	**2.0**[c]	**10**	gavage	gestation (10 days)	reproduction	pup body weight, testes weight	MacKenzie and Angevine (1981)
Benzo(a)pyrene	benzo(a)pyrene	mouse	33.3	nv	food	up to 115 days	survival	survival	Neal and Rigdon (1967)
Naphthalene	naphthalene	mouse	**133**	nv	gavage	90 days	survival, growth	body weight, adult survival	Shopp et al. (1984)
Naphthalene	naphthalene	mouse	nv	**300**	gavage	8 days of pregnancy	survival, reproduction	maternal survival; litter size	Plasterer et al. (1985)
Phthalates									
BEHP	BEHP	mouse	**44**	**91**	food	17 days (pregnancy)	reproduction	fetal abnormalities increased	Tyl et al. (1988)
BEHP	BEHP	guinea pig	93	nv	food	1 year	survival, growth	life expectancy, body weight	Carpenter et al. (1953)
BEHP	BEHP	mouse	14	136	food	>24 weeks (2 generations)	reproduction	number of litters, viability	Lamb et al. (1987)
BEHP	BEHP	mouse	70	190	food	18 days (pregnancy)	reproduction	fetal death	Shiota et al. (1980)
BEHP	BEHP	mouse	91	191	food	17 days (pregnancy)	growth	maternal body weight	Tyl et al. (1988)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	**250**	**750**	food	multi-generational (2 generations)	growth, reproduction	body weight, reduced no. live pups/litter and no. implantations, reduced offspring body weight, delayed onset of puberty	Tyl et al. (2004)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	831	nv	food	14 days	growth	male body weight	Agarwal et al. (1985)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	nv	845	food	11 days (pregnancy)	reproduction	maternal weight; post-implantation embryo loss	Ema et al. (1994)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	991	nv	food	20 days (pregnancy)	survival	maternal mortalities	Ema et al. (1992a; 1992b)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Butyl benzyl phthalate	butyl benzyl phthalate	rat	nv	991	food	20 days (pregnancy)	reproduction	fetal death, fetal weight, malformations and resorptions	Ema et al. (1992a)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	nv	1325	food	14 days	growth	male body weight	Agarwal et al. (1985)
Butyl benzyl phthalate	butyl benzyl phthalate	rat	1570	nv	food	14 days	survival	male survival	Agarwal et al. (1985)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	**16**[c]	**80**	food	~24 weeks (2 gen)	reproduction	fertility, pup weight, pup viability, mating	Wine et al. (1997)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	641	nv	food	~24 weeks (2 gen)	survival		Wine et al. (1997)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	320	641	food	~24 weeks (2 gen)	growth	body weight	Wine et al. (1997)
Di-n-butyl phthalate	di-n-butyl phthalate	mouse	660	nv	food	18 days (pregnancy)	growth	maternal weight	Shiota et al. (1980)
Di-n-butyl phthalate	di-n-butyl phthalate	mouse	350	660	food	18 days (pregnancy)	reproduction	decrease in male fetal weight	Shiota et al. (1980)
Di-n-butyl phthalate	di-n-butyl phthalate	rat	200	999	food	1 year	survival		Smith (1953)
Other SVOCs									
Benzoic acid	benzoic acid	rat	**80**	nv	diet	18 months	survival, growth	body weight, survival	Ignat'ev 1965 (as cited in IRIS (EPA 2006))
Benzoic acid	benzoic acid	rat	50	**750**	diet	long-term	growth	body weight	Marquardt 1980 (as cited in IRIS (EPA 2006))
Benzoic acid	sodium benzoate	hamster	300	nv	diet		survival, reproduction	no maternal toxicity or fetal toxicity	FDRL 1972 (as cited in IRIS (EPA 2006))
Biphenyl	biphenyl	rat	50	250	diet	3-generation	survival	longevity	Ambrose et al. 1960 (as cited in IRIS (EPA 2006))
Hexachlorobenzene	hexachloro-benzene	mink, ferret	**0.026**[c]	**0.13**	food	331 days	reproduction	birth weight	Bleavins et al. (1984)
Hexachlorobenzene	hexachloro-benzene	rat	nv	0.80	food	4 generation	reproduction	weanling weight	Grant et al. (1977)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Hexachlorobenzene	hexachloro-benzene	rat	1.28	nv	food	>120 days	reproduction, behavior	number of pups and weights	Lilienthal et al. (1996)
Hexachlorobenzene	hexachloro-benzene	rat	3.2	nv	food	2 generation	survival, growth		Arnold et al. (1985)
Hexachlorobenzene	hexachloro-benzene	rat	0.64	3.2	food	2 generation	reproduction	decreased viability	Arnold et al. (1985)
Hexachlorobenzene	hexachloro-benzene	rat	nv	4.8	food	~200 d days	reproduction	pup survival	Kitchin et al. (1982)
Hexachlorobenzene	hexachloro-benzene	rat	11	nv	food	> 100 days	survival, growth		Kitchin et al. (1982)
Hexachlorobenzene	hexachloro-benzene	mink, ferret	3.2	16	food	331 days	survival		Bleavins et al. (1984)
Hexachlorobenzene	hexachloro-benzene	rat	13	26	food	4 generation	survival		Grant et al. (1977)
Phenol	phenol	rat	**60**	**120**	gavage	gestational days 6 - 15	growth	maternal body weight	Argus Research Laboratories 1997 (as cited in IRIS (EPA 2006))
Phenol	phenol	rat	**60**	**120**	gavage	not specified	reproduction	decreased fetal body weight	Charles River Laboratories 1988 and NTP 1983a (as cited in IRIS (EPA 2006))
Phenol	phenol	mouse	140	280	gavage	gestational days 6 - 15	survival, growth	survival and reduced body weight	NTP 1983b (as cited in IRIS (EPA 2006))
PCBs									
Total PCBs	Clophen A50	mink	**0.045**[d,e]	**0.089**[e]	food	18 months	reproduction	kit growth	Brunström et al. (2001)
Total PCBs	Aroclor 1254	mink	nv	0.13	food	6 months	reproduction	reduced kit growth rate	Wren et al. (1987)
Total PCBs	Aroclor 1254	mink	nv	0.22	food	4 and 9 months prior to giving birth	reproduction	number of offspring per female, decrease in pup body weight	Ringer (1983)
Total PCBs	Aroclor 1254	mink	0.13	0.26	food	4 months	reproduction	Number of kits born alive (0% at 4 weeks)	Aulerich and Ringer (1977)
Total PCBs	Aroclor 1254	mink	nv	0.39	food	88-102 days	reproduction	number of kits whelped and born alive (0%)	Aulerich et al. (1985)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Total PCBs	mixture composition not reported	mink	nv	0.51	food	66 days	reproduction	number of kits born alive	Jensen et al. (1977)
Total PCBs	Aroclor 1242	mink	nv	0.65	food	8 months	reproduction	reproductive failure	Bleavins et al. (1980)
Total PCBs	Aroclor 1254	mouse	**0.13**[b,f]	**1.3**[f]	food	7.5 to 18 months	reproduction	offspring survival, offspring body weight	Linzey (1987, 1988)
Total PCBs	Aroclor 1254	mink	nv	1.31	food	4 weeks	weight gain in adults	weight gain in adults	Hornshaw et al. (1986)
Total PCBs	Aroclor 1254	mink	nv	1.64	food	3 months	reproduction	all whelps stillborn	Kihlstrom et al. (1992)
Total PCBs	Aroclor 1254	mink	1.2	1.8	food	28 days	growth	female growth	Aulerich et al. (1986)
Total PCBs	Clophen A50	mink	nv	2.0	food	3 months	reproduction	all whelps stillborn	Kihlstrom et al. (1992)
Total PCBs	Aroclor 1254	mink	1.5	2.4	food	28 days	growth	male and female growth	Aulerich et al. (1986)
Total PCBs	Aroclor 1016	mink	nv	2.6	food	8 months	reproduction/survival	birth weight and growth rate of kits, and 25 % adult female survival	Bleavins et al. (1980)
Total PCBs	Aroclor 1254	rat	3.7	7.5	food	10 days during gestation	reproduction	offspring body weight	Spencer (1982)
Organochlorine Pesticides									
beta-HCH	beta-HCH	rat	**5.7**	**31**	food	13 weeks	growth, survival	body weight, survival	Van Velsen et al. (1986)
beta-HCH	beta-HCH	rat	64	nv	food	2 weeks	growth	body weight	Srinivasan et al. (1991)
DDT	o,p'-DDT	rat	0.24	nv	food	2 generation	reproduction	litter size and weight and uterine involution	Duby et al. (1971)
DDT	p,p'-DDT	mouse	0.6	nv	food	5 generation	survival, growth, reproduction	adult survival, growth, number of pregnancies, number of births, litter size, pup growth/survival	Tarjan and Kemeny (1969)
DDT	p,p'- DDT	rat	1.0	nv	food	2 generation	reproduction	litter size and weight and uterine involution	Duby et al. (1971)
Total DDT	technical DDT	rat	**1.2**	nv	food	2 generations	reproduction	litter size and weight and uterine involution	Duby et al. (1971)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Total DDT	form not specified, likely DDT mixture	mouse	1.3	nv	food	120 days	survival	no effect on survival	Ware and Good (1967)
Total DDT	form not specified, likely DDT mixture	mouse	nv	**1.3**	food	120 days	reproduction	litter size	Ware and Good (1967)
Total DDT	technical DDT	rat	1.6	nv	food	23 months	growth, survival, reproduction	adult survival, growth, viable litter size, reproductive life-span	Ottoboni (1972)
Total DDT	technical DDT	rat	nv	2.0	food	7.5 weeks	reproduction	fertility	Nickerson and Sniffen (1973)
Total DDT	form not specified, likely DDT mixture	rat	0.8	4.0	food	2 years	reproduction	number of young surviving to weaning (63% vs. 87% lower dose and 88% in control)	Fitzhugh (1948)
Total DDT	technical DDT	rat	6.7	13.4	food	36 weeks	reproduction	litter size, mating and reproductive success	Jonsson et al. (1976)
DDT	p,p'-DDT	rat	1.6	16	food	6 months	reproduction	offspring growth	Clement and Okey (1974)
Total DDT	form not specified, likely DDT mixture	white lab mouse	nv	37	food	F0 mating, gestation and weaning+F1 breeding	survival	no effect on survival	Cannon and Holcomb (1968)
Total DDT	technical DDT	Oldfield mouse	2.4	nv	food	15 months	survival, reproduction	adult survival, litter size, litters per pair	Wolfe et al. (1979)
DDT	o,p'-DDT	rat	4.0	nv	food	18-23 weeks	reproduction	offspring survival, fertility, fecundy, growth	Wrenn et al. (1971)
Total DDT	technical DDT	mouse	9.2	46	food	6 generation	survival, reproduction	lifespan, pup survival	Turusov et al. (1973)
Total DDT	technical DDT	rat	13	nv	food	37 weeks	survival	no effect on survival	Jonsson et al. (1976)
Total DDT	technical DDT (DDD, DDE, DDT)	rat	16	nv	food	3 generation	survival, growth, reproduction	adult survival, growth, fertility, viability, stillbirths, litter size, abnormalities, pup survival	Ottoboni (1969)
DDT	p,p'-DDT	mouse	18	nv	food	2 years	survival	no effect on survival	Thorpe and Walker (1973)
Total DDT	pp'-DDT, '-DDD, -DDE	rat	21	nv	food	6 weeks	growth, survival	survival, body weight (males only)	Banerjee et al. (1996)

Table 7. Summary of Acceptable Toxicity Studies for the Selection of Mammal Dietary TRVs

Chemical	Chemical Form	Test Species	NOAEL[a] (mg/kg bw/day)	LOAEL[b] (mg/kg bw/day)	Exposure Route	Exposure Duration	Endpoint	Effect Endpoint	Source
Methoxychlor	methoxychlor	rat	nv	**56**	food	gestation day 0 to postnatal day 22 (adult); postnatal day 28 to 100 (young)	growth, reproduction	body weight; offspring growth rate, litter size, sex development of offspring	You et al. (2002)
Methoxychlor	methoxychlor	rat	**17**	86	food	gestation day 15, postnatal day 10	reproduction, growth	maternal body weight, offspring body weight, delayed onset of puberty	Masutomi et al. (2003)
Methoxychlor	technical methoxychlor	rat	nv	80	food	parents treated, weanlings treated 8 weeks thru mating	reproduction	% mated, % littered	Harris et al. (1974)
Methoxychlor	technical methoxychlor	rat	nv	168	food	pre-mating thru weaning	reproduction	% mated, litter production and size	Harris et al. (1974)
VOCs									
Acetone	acetone, 99% pure	rat	**1,650**	**3,259**	drinking water	2 or 13 weeks	growth	body weight	Dietz et al. (1991)
Ethylbenzene	ethylbenzene	rat	**250**	**750**	gavage	13 weeks	growth	reduced body weight	Mellert et al. (2007)

[a] NOAEL and LOAEL TRVs, expressed as a dietary dose (mg/kg bw/day), were calculated from literature studies based on body weight, ingestion rate, and dietary concentrations.

[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 10.

[c] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5.

[d] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 2.

[e] Selected NOAEL and LOAEL for the screening-level risk assessment.

[f] Selected NOAEL and LOAEL for the baseline risk evaluation.

bw – body weight
LOAEL – lowest-observed-effect concentration
BEHP – bis(2-ethylhexyl)phthalate
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HCH – hexachlorocyclohexane
NOAEL – no-observed-effect concentration
nv – no value
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
TRV – toxicity reference value
SVOC - semivolatile organic compound
VOC – volatile organic compound

BOLD represents selected NOAEL and LOAEL TRVs.

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ATTACHMENT 2: METHODS FOR ESTIMATING TISSUE CONCENTRATIONS

Tissue data were not collected from the Harbor Oil Superfund Study Area for chemistry analysis. In order to conduct the ecological risk assessment (ERA), chemical concentrations in various tissue types were estimated from abiotic concentrations. Estimated tissue concentrations were used to assess risks to fish via fish tissue residues and to assess risks to various ecological receptors via dietary exposures.

Aquatic species (i.e., benthic invertebrates and fish) tissue concentrations were estimated from sediment using biota-sediment accumulation factors (BSAFs), and terrestrial species (i.e., terrestrial plants, invertebrates [earthworms] and small mammals) concentrations were estimated from soil using bioaccumulation factors (BAFs). BSAFs and BAFs represent the steady-state relationship between chemical concentrations in sediment or soil and tissue. Other assumptions (i.e., tissue-specific moisture and lipid content, sediment organic carbon [OC] content) were also used to calculate biota tissue-residue concentrations.

Equations 1 and 2 present how BSAFs are commonly derived as a ratio for inorganic (metals) and organic compounds, respectively.

$$BSAF = \frac{C_{tiss,dw}}{C_{sed,dw}}$$ **Equation 1**

Where:

BSAF	ratio	chemical - and species-specific biota-sediment accumulation factor
$C_{tiss,dw}$	mg/kg dw	dry weight concentration in tissue
$C_{sed,dw}$	mg/kg dw	dry weight concentration in sediment

$$BSAF = \frac{C_{tissue} / Lipid_{tiss}}{C_{sed} / OC_{sed}}$$ **Equation 2**

Where:

BSAF	ratio	chemical - and species-specific biota-sediment accumulation factor
$C_{tiss,ww}$	mg/kg ww	wet weight concentration in tissue
$Lipid_{tiss}$	fraction	lipid content in tissue (expressed as a fraction)
$C_{sed,dw}$	mg/kg dw	dry weight concentration in sediment
OC_{sed}	fraction	organic carbon content in sediment (expressed as a fraction)

Aquatic benthic invertebrate and fish tissue concentrations (C_{tiss}) used in the ERA were derived from Force Lake surface sediment concentrations (C_{sed}) by algebraically rearranging Equations 1 and 2 and using literature-based BSAFs and generic assumptions regarding moisture content and lipid content (Table 1).

Moisture content was needed to convert BSAF-estimated dry weight tissue concentrations (for metals) into wet weight tissue concentrations. For organic compounds, Force Lake sediment concentrations were OC-normalized using the sample-specific total organic carbon (TOC) value (Table 2), and tissue concentrations were converted from lipid-normalized concentrations to wet weight concentrations using an average receptor-specific lipid content.

Table 1. Assumptions Used to Estimate Tissue Concentrations Using BSAFs

Parameter	Assumption	Source
Sediment total organic carbon	see Table 2	Force Lake data
Moisture content – benthic invertebrates	79%	EPA (1993)
Moisture content – fish	72%	EPA (1993)
Lipid content – benthic invertebrates	1.2%	EPA (2008)[a]
Lipid content – fish	3.7%	EPA (2008)[b]
Lipid content – pumpkinseed	3.1%	EPA (2008)[c]
Lipid content – brown bullhead	2.6%	EPA (2008)[d]

[a] Average reported lipid content for all benthic invertebrates.
[b] Average reported lipid content for pumpkinseed, carp, and brown bullhead.
[c] Average reported lipid content for pumpkinseed.
[d] Average reported lipid content for brown bullhead.
BSAF – biota-sediment accumulation factor EPA – US Environmental Protection Agency

Table 2. TOC Data Used to Estimate Organic Compound Concentrations in Fish Tissue

Surface Sediment Sampling Location	TOC (%)
SE-01	6.71
SE-02	5.1
SE-03	6.54
SE-04	10.4
SE-05	6.02
SE-06	10.6
SE-07	13.1
SE-08	3.02
SE-09	8.44
SE-10	7.07
SE-11	1.34

TOC – total organic carbon

For metals, the following equation was used to estimate dry weight aquatic benthic invertebrate and fish tissue concentrations on a sample-by-sample basis:

$$C_{tiss,dw} = C_{sed,dw} \times BSAF \qquad \textbf{Equation 3}$$

Where:

$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
$C_{sed,dw}$	mg/kg dw	sample-specific dry weight Force Lake sediment concentration
BSAF	ratio	chemical and receptor-specific biota-sediment accumulation factor

Metal dry weight tissue concentrations were then converted into wet weight tissue concentrations using the following equation and percent moisture assumptions:

$$C_{tiss,ww} = C_{tiss,dw} \times (1 - M_{tiss}) \qquad \textbf{Equation 4}$$

Where:

$C_{tiss,ww}$	mg/kg ww	sample- and receptor-specific estimated wet weight tissue concentration
$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
M_{tiss}	fraction	receptor-specific moisture content in tissue (expressed as a fraction); M_{tiss} = 0.79 for aquatic benthic invertebrates, and M_{tiss} = 0.72 for fish (Table 1)

For organic compounds, the following equation and assumptions were used to derive wet weight aquatic benthic invertebrate and fish tissue concentrations:

$$C_{tiss,ww} = \left[\frac{C_{sed,dw}}{OC_{sed}} \times BSAF\right] \times Lipid_{tiss} \qquad \textbf{Equation 5}$$

Where:

$C_{tiss,ww}$	mg/kg ww	sample- and receptor-specific estimated wet weight tissue concentration
$C_{sed,dw}$	mg/kg dw	sample-specific dry weight Force Lake sediment concentration
OC_{sed}	fraction	sample-specific TOC in sediment (expressed as a fraction)
BSAF	ratio	chemical and receptor-specific biota-sediment accumulation factor
$Lipid_{tiss}$	fraction	receptor-specific lipid content in tissue (expressed as a fraction); $Lipid_{tiss}$ = 0.012 for aquatic benthic invertebrates, $Lipid_{tiss}$ = 0.031 for pumpkinseed, and $Lipid_{tiss}$ = 0.026 for brown bullhead (Table 1)

Equation 6 presents how BAFs are commonly derived as a ratio for both inorganic (metals) and organic compounds.

$$BAF = \frac{C_{tissue}}{C_{soil}} \qquad \textbf{Equation 6}$$

Where:

BAF	ratio	chemical - and species-specific bioaccumulation factor
$C_{tiss,dw}$	mg/kg dw	dry weight concentration in tissue
$C_{sed,dw}$	mg/kg dw	dry weight concentration in soil

Terrestrial plant, terrestrial invertebrate (earthworms), and small mammal tissue concentrations (C_{tiss}) used in the ERA were derived from wetland surface soil concentrations (C_{sed}) by algebraically rearranging Equation 6 and using literature-based BAFs and generic assumptions regarding moisture content (Table 3). Moisture content was needed to convert BAF-estimated dry weight tissue concentrations into wet weight tissue concentrations.

Table 3. Assumptions Used to Estimate Tissue Concentrations Using BAFs

Parameter	Assumption	Source
Moisture content – terrestrial plants	79%	EPA (1993)
Moisture content – terrestrial invertebrates	71%[a]	EPA (1993)
Moisture content – small terrestrial mammals	68%	EPA (1993)

[a] Moisture content was based on the average earthworm percent moisture.

BAF – bioaccumulation factor EPA – US Environmental Protection Agency

The following equation and assumptions were used to estimate dry weight terrestrial species tissue concentrations on a sample-by-sample basis:

$$C_{tiss,dw} = C_{soil,dw} \times BAF \qquad \textbf{Equation 7}$$

Where:

$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
$C_{soil,\,dw}$	mg/kg dw	sample-specific dry weight wetland soil concentration
BAF	ratio	chemical- and receptor-specific biota accumulation factor

Dry weight tissue concentrations were then converted into wet weight tissue concentrations using the following equation and percent moisture assumption:

$$C_{tiss,ww} = C_{tiss,dw} \times (1 - M_{tiss}) \qquad \textbf{Equation 8}$$

Where:

$C_{tiss,ww}$	mg/kg ww	sample- and receptor-specific estimated wet weight tissue concentration
$C_{tiss,dw}$	mg/kg dw	sample- and receptor-specific estimated dry weight tissue concentration
M_{tiss}	fraction	receptor-specific moisture in tissue (expressed as a fraction); M_{tiss} = 0.79 for terrestrial plants, M_{tiss} = 0.71 for terrestrial invertebrates, and M_{tiss} = 0.68 for small mammals (Table 3)

A search for benthic invertebrate and fish literature-based BSAF was conducted for all sediment contaminants of interest (COIs) (i.e., chemicals with detected concentrations in Force Lake surface sediment). BSAFs were selected from a variety of compilation sources; their availability varied depending on the chemical class and modeled species. BSAFs were selected based on the following hierarchy:

- Fish and invertebrate BSAFs for organic compounds were based on US Environmental Protection Agency's (EPA's) BSAF database (EPA 2008) when available.

- Benthic invertebrate BSAFs for inorganic chemicals (i.e., metals) were based on mean BSAFs reported by the Oak Ridge National Laboratory (ORNL) (1998).
- Fish BSAFs were derived as the mean BSAF reported in the collection of BSAFs compiled by PTI (1995a, b).
- A surrogate BSAF was used for some related chemicals (e.g., bis(2-ethylhexyl) phthalate [BEHP] was used as a surrogate for other phthalates with no BAF).
- A default value of 1 was used for all sediment COIs with no published value from the above sources. The use of this default value assumed that sediment and tissue concentrations were equal, which is a conservative assumption for chemicals that are regulated by fish or benthic invertebrates (e.g., metals) or do not accumulate (e.g., VOCs) and would therefore have BSAFs lower than 1. The default BSAF assumption of 1 could underestimate risks for bioaccumulative chemicals; however, literature-based BSAFs are available for the key known bioaccumulative chemicals, such as PCBs and DDTs.

The US Army Corps of Engineers (USACE) BSAF database (2008) was searched to obtain BSAFs; however, units for BSAFs in this database are not clearly presented (i.e., whether BSAFs for organic compounds were expressed as lipid- and OC-normalized tissue and sediment concentrations, respectively), and thus these BSAFs were not used.

A search for terrestrial plant, invertebrate (earthworm), and small mammal literature-based BAFs was conducted for all soil COIs (i.e., all chemicals with detected concentrations in wetland soil). BAFs were selected from a variety of compilation sources based on the following hierarchy:

- BAFs for terrestrial plants, terrestrial invertebrates, and small terrestrial mammals were selected from the available literature from ORNL (Bechtel Jacobs 1998; Lockheed-Martin Energy Systems 1998a, b) when available.
- The guidance for ecological soil screening levels (EPA 2007) was used to develop plant, invertebrate, and small mammals BAFs for those COIs for which no ORNL BAF was available.
- BAFs for terrestrial plants were derived from regressions reported in Travis and Arms (1988) and using chemical-specific K_{ow} values.
- A PCB BAF for small mammals was developed based on Moore et al. (2003).
- A surrogate BAF was used for some related chemicals (e.g., BEHP was used as a surrogate for other phthalates with no BAF).
- A default value of 1 was used for all soil COIs with no published value from the above sources. The use of this default value assumed that soil and tissue concentrations were equal, which is a conservative assumption for chemicals that are regulated (e.g., metals) or do not accumulate (e.g., VOCs) and would therefore have BAFs lower than 1. The default BAF assumption of 1 could underestimate risks for

bioaccumulative chemicals; however, literature-based BAFs are available for the key known bioaccumulative chemicals, such as PCBs and DDTs.

Tables 4 and 5 present the aquatic invertebrate and fish BSAFs used in the ERA. Tables 6 through 8 present the terrestrial plant, earthworm, and small mammal BAFs that were used in the ERA. Table 9 presents the K_{ow} values that were used to derive some terrestrial plant BAFs.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Metals (dw/dw)		
Aluminum	1	No invertebrate BSAF was available from the literature; default value was used.
Antimony	1	No invertebrate BSAF was available from the literature; default value was used.
Arsenic	0.240	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 49 BSAFs ranging from 0.018 to 0.889 compiled from multiple sources; median BSAF was 0.127.
Barium	1	No invertebrate BSAF was available from the literature; default value was used.
Beryllium	1	No invertebrate BSAF was available from the literature; default value was used.
Cadmium	3.438	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 88 BSAFs ranging from 0.049 to 41.55 compiled from multiple sources; median BSAF was 0.614.
Chromium	0.206	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 26 BSAFs ranging from 0.015 to 1.101 compiled from multiple sources; median BSAF was1.108.
Cobalt	1	No invertebrate BSAF was available from the literature; default value was used.
Copper	2.14	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 74 BSAFs ranging from 0.032 to 16.63 compiled from multiple sources; median BSAF was1.647.
Lead	0.331	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 83 BSAFs ranging from 0.004 to 7.08 compiled from multiple sources; median BSAF was 0.066.
Mercury	1.204	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 13 BSAFs ranging from 0.286 to 2.868 compiled from multiple sources; median BSAF was 1.081.
Nickel	1.313	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 16 BSAFs ranging from 0.397 to 5.746 compiled from multiple sources; median BSAF was 0.818.
Selenium	1	No invertebrate BSAF was available from the literature; default value was used.
Vanadium	1	No invertebrate BSAF was available from the literature; default value was used.
Zinc	3.473	Based on non-depurated mean BSAF reported by ORNL (1998); mean was based on 84 BSAFs ranging from 0.026 to 14.512 compiled from multiple sources; median BSAF was 2.33
PAHs (lipid/OC)		
2-Methylnaphthalene	3.194	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 17 BSAFs ranging from 0.00369 to 29.42.
Acenaphthene	0.252	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 42 BSAFs ranging from 0.00048 to 1.43.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Acenaphthylene	0.508	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 52 BSAFs ranging from 0.00105 to 5.07.
Anthracene	0.659	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 63 BSAFs ranging from 0.00030 to 23.7.
Benzo(a)anthracene	0.545	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 66 BSAFs ranging from 0.00014 to 11.8.
Benzo(a)pyrene	0.383	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 64 BSAFs ranging from 0.00016 to 9.51.
Benzo(b)fluoranthene	1.45	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 8 BSAFs ranging from 0.00144 to 8.03.
Benzo(g,h,i)perylene	0.691	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 55 BSAFs ranging from 0.00013 to 16.8.
Benzo(k)fluoranthene	2.09	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 6 BSAFs ranging from 0.00226 to 11.0.
Chrysene	0.554	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 43 BSAFs ranging from 0.00713 to 7.30.
Dibenzo(a,h)anthracene	1.89	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 28 BSAFs ranging from 0.00004 to 37.1.
Fluoranthene	0.431	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 70 BSAFs ranging from 0.00044 to 4.54.
Fluorene	0.628	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 56 BSAFs ranging from 0.00053 to 10.7.
Indeno(1,2,3-cd)pyrene	1.02	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 47 BSAFs ranging from 0.00006 to 19.6.
Naphthalene	0.588	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 22 BSAFs ranging from 0.00043 to 3.15.
Phenanthrene	0.496	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 65 BSAFs ranging from 0.00016 to 8.86.
Pyrene	0.318	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 70 BSAFs ranging from 0.00037 to 3.33.
Total PAHs	0.924	Based on the mean of the average BSAFs for individual PAHs reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrates; individual PAH BSAFs ranged from 0.00004 to 37.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
PCBs (lipid/OC)		
Total PCBs	2.57	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 155 BSAFs ranging from 0.00715 to 27.9.
Phthalates (lipid/OC)		
BEHP	7.75	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 3 BSAFs ranging from 0.81 to 14.0.
Butyl benzyl phthalate	7.75	Based on the BEHP BSAF.
Di-n-butyl phthalate	7.75	Based on the BEHP BSAF.
Other SVOCs (lipid/OC)		
Hexachlorobenzene	1	No invertebrate BSAF was available from the literature; default value was used.
Phenol	1	No invertebrate BSAF was available from the literature; default value was used.
Pentachlorophenol	1	No invertebrate BSAF was available from the literature; default value was used.
Pesticides (lipid/OC)		
2,4'-DDD	4.32	Based on the 4,4'-DDD BSAF.
4,4'-DDD	4.32	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 19 BSAFs ranging from 0.0343 to 45.0.
4,4'-DDE	5.94	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all aquatic invertebrate species; mean was based on 74 BSAFs ranging from 0.393 to 48.5.
Total DDTs	5.21	Based on the weighted average BSAF for the three DDT components detected in Force Lake: 16% 2,4′-DDD (mean BSAF of 4.32 from EPA (2008)), 29% 4,4′-DDD (mean BSAF of 4.32 from EPA (2008)), and 55% 4,4'-DDE (mean BSAF of 5.94 from EPA (2008)); DDT metabolite BSAFs ranged from 0.034 to 49.
delta-BHC	1	No invertebrate BSAF was available from the literature; default value was used.
Methoxychlor	1	No invertebrate BSAF was available from the literature; default value was used.
Ethylbenzene	1	No invertebrate BSAF was available from the literature; default value was used.
VOCs (lipid/OC)		
Acetone	1	No invertebrate BSAF was available from the literature; default value was used.
Carbon disulfide	1	No invertebrate BSAF was available from the literature; default value was used.
Methyl ethyl ketone	1	No invertebrate BSAF was available from the literature; default value was used.

Table 4. Aquatic Invertebrate BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Toluene	1	No invertebrate BSAF was available from the literature; default value was used.
Acetone	1	No invertebrate BSAF was available from the literature; default value was used.

[a] All metal BSAFs are expressed as the ratio of tissue concentration (in dry weight) over sediment concentration (in dry weight); all BSAFs for organic compounds are expressed as the ratio of tissue concentration (as a lipid-normalized concentration) over sediment concentration (as an OC-normalized concentration).

BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
BSAF – biota-sediment accumulation factor
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
OC – organic carbon
ORNL – Oak Ridge National Laboratory
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 5. Fish BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Metals (dw/dw)		
Aluminum	1	No fish BSAF was available from the literature; default value was used.
Arsenic	0.12	This was the only fish BSAF presented in PTI (1995b).
Barium	1	No fish BSAF was available from the literature; default value was used.
Cadmium	0.785	Based on the mean BSAF reported by PTI (1995b); mean was based on 9 BSAFs ranging from 0.043 to 2.0 compiled from one location.
Chromium	0.043	This was the only fish BSAF presented in PTI (1995b).
Cobalt	1	No fish BSAF was available from the literature; default value was used.
Copper	1	No fish BSAF was available from the literature; default value was used.
Lead	0.180	Based on the mean BSAF reported by PTI (1995b); mean was based on 9 BSAFs ranging from 0.028 to 0.43 compiled from one location.
Mercury	0.38	Only fish BSAF value presented in PTI (1995b)
Nickel	1	No fish BSAF was available from the literature; default value was used.
Vanadium	1	No fish BSAF was available from the literature; default value was used.
Zinc	1.83	Based on the mean BSAF reported by PTI (1995b); mean was based on 10 BSAFs ranging from 0.13 to 5.0 compiled from two locations.
PAHs (lipid/OC)		
2-Methylnaphthalene	0.147	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 14 BSAFs ranging from 0.0109 to 0.972.
Acenaphthene	0.0313	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 11 BSAFs ranging from 0.00484 to 0.0602.
Acenaphthylene	0.0138	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 11 BSAFs ranging from 0.00032 to 0.0287.
Anthracene	0.0078	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 15 BSAFs ranging from 0.00020 to 0.0148.
Benzo(a)anthracene	0.0135	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 8 BSAFs ranging from 0.00030 to 0.0941.
Benzo(a)pyrene	0.0021	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 4 BSAFs ranging from 0.00023 to 0.0040.

Table 5. Fish BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
Benzo(b)fluoranthene	0.0025	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 5 BSAFs ranging from 0.00022 to 0.0043.
Benzo(g,h,i)perylene	0.0250	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 3 BSAFs ranging from 0.00118 to 0.0699.
Benzo(k)fluoranthene	0.0023	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 5 BSAFs ranging from 0.00021 to 0.0041.
Chrysene	0.0100	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 8 BSAFs ranging from 0.00032 to 0.0636.
Dibenzo(a,h)anthracene	0.0022	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 5 BSAFs ranging from 0.00031 to 0.0043.
Dibenzofuran	0.0259	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 12 BSAFs ranging from 0.00211 to 0.0496.
Fluoranthene	0.0056	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 15 BSAFs ranging from 0.00008 to 0.0383.
Fluorene	0.0626	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 16 BSAFs ranging from 0.00058 to 0.5256.
Indeno(1,2,3-cd)pyrene	0.0144	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 6 BSAFs ranging from 0.00021 to 0.0756.
Naphthalene	0.135	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 11 BSAFs ranging from 0.0123 to 0.813.
Phenanthrene	0.0237	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 17 BSAFs ranging from 0.00021 to 0.161.
Pyrene	0.0158	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 8 BSAFs ranging from 0.00025 to 0.0638.
Total PAHs	0.0300	Based on the mean of average BSAFs for individual PAHs reported in EPA's BSAF database (EPA 2008) for all fish species.

Table 5. Fish BSAFs Used in the ERA

Chemical	BSAF[a]	Source of and Details on Selected Value
PCBs (lipid/OC)		
Total PCBs	6.45	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008) for all fish species; mean was based on 285 BSAFs ranging from 0.00375 to 258.
Other SVOCs (lipid/OC)		
Pentachlorophenol	1	No fish BSAF was available from the literature; default value was used.
Pesticides (lipid/OC)		
2,4'-DDD	0.045	Based on the geometric mean BSAF reported by PTI (1995a).
4,4'-DDD	0.83	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008).;
4,4'-DDE	5.00	Based on the mean BSAF reported in EPA's BSAF database (EPA 2008).
Total DDTs	3.0	Based on the weighted average BSAFs for the three DDT components detected in Force Lake:16% 2,4′-DDD (geometric mean BSAF of 0.045 from PTI (1995a)), 29% 4,4′-DDD (mean BSAF of 0.83 from EPA (2008)), and 55%4,4'-DDE (mean BSAF of 5.00 from EPA (2008))
VOCs (lipid/OC)		
Acetone	1	No fish BSAF was available from the literature; default value was used.
Carbon disulfide	1	No fish BSAF was available from the literature; default value was used.
Methyl ethyl ketone	1	No fish BSAF was available from the literature; default value was used.
Toluene	1	No fish BSAF was available from the literature; default value was used.

[a] All metal BSAFs are expressed as the ratio of tissue concentration (in dry weight) over sediment concentration (in dry weight); all BSAFs for organic compounds are expressed as the ratio of tissue concentration (as a lipid-normalized concentration) over sediment concentration (as an OC-normalized concentration).

BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
BSAF – biota sediment accumulation factor
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 6. Terrestrial Plant BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source of and Details on Selected Value
Metals		
Aluminum	1.0	No plant BAF was available from the literature; default value was used.
Antimony	$C_{plant} = e^{(0.938*LN(Csoil)-3.233)}$	Based on the BAF reported in EPA (2007).
Arsenic	0.454	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 122 BAFs ranging from 0.00006 to 9.074 compiled from multiple sources; median BAF was 0.0375.
Cadmium	1.359	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 207 BAFs ranging from 0.0087 to 22.879 compiled from multiple sources; median BAF was 0.586.
Chromium	0.041	Based on the BAF reported in EPA (2007).
Cobalt	0.0075	Based on the BAF reported in EPA (2007).
Copper	0.341	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 180 BAFs ranging from 0.0011 to 7.4 compiled from multiple sources; median BAF was 0.124.
Lead	0.245	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 189 BAFs ranging from 0.00011 to 10.601 compiled from multiple sources; median BAF was 0.0389.
Mercury	1.481	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 145 BAFs ranging from 0.00145 to 12.23 compiled from multiple sources; median BAF was 0.652.
Nickel	0.749	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 111 BAFs ranging from 0.00217 to 22.214 compiled from multiple sources; median BAF was 0.018.
Selenium	2.253	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 158 BAFs ranging from 0.02 to 77compiled from multiple sources; median BAF was 0.672.
Vanadium	0.00485	The plant BAF of 0.00485 was based EPA (2007). The variability in vanadium BAFs from the literature is unknown.
Zinc	1.021	Based on the mean BAF reported by Bechtel Jacobs (1998); mean was based on 220 BAFs ranging from 0.00855 to 34.286 compiled from multiple sources; median BAF was 0.366.
PAHs		
2-Methylnaphthalene	12.2	Based on the naphthalene BAF.
Benzo(a)pyrene	$C_{plant} = e^{(0.975*LN(Csoil)-2.0615)}$	Based on the BAF reported in EPA (2007).
Naphthalene	12.2	Based on the BAF reported in EPA (2007).
Total PAHs	6.15	Based on the average BAF of the two individual PAHs[a] with BAFs (benzo[a]pyrene and naphthalene) reported in EPA (2007); the benzo(a)pyrene BAF (0.103) was estimated using the maximum benzo(a)pyrene soil concentration (4,000 µg/kg dw) and the BAF equation reported by EPA (2007).
Phthalates		
BEHP	0.00179	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} =

Table 6. Terrestrial Plant BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source of and Details on Selected Value
		1.588 – (0.578 log K_{ow})[b].
Butyl benzyl phthalate	0.00179	Based on the BEHP BAF.
Di-n-butyl phthalate	0.128	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Other SVOCs		
Benzoic acid	1.0	No plant BAF was available from the literature; default value was used.
Biphenyl	1.0	No plant BAF was available from the literature; default value was used.
Hexachlorobenzene	0.0189	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Pentachlorophenol	1.0	No plant BAF was available from the literature; default value was used.
Phenol	5.55	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
PCBs		
Total PCBs	0.00519	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Pesticides		
Total DDTs	$C_{plant} = e^{(0.7524*LN(Csoil)-2.5119)}$	Based on the BAF reported in EPA (2007).
delta-BHC	0.157	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Methoxychlor	0.0585	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
VOCs		
Acetone	53.3	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].
Ethylbenzene	0.348	BAF was calculated using the following equation reported in Travis and Arms (1988): log BAF_{plant} = 1.588 – (0.578 log K_{ow})[b].

[a] Average BAF of naphthalene (12.2) and benzo(a)pyrene (0.103). Benzo(a)pyrene BAF was estimated using the maximum soil concentration (4,000 mg/kg dw).

[b] Log K_{ow} values are presented in Table 6.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 7. Earthworm BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source and Details on Selected Value
Metals		
Aluminum	1	No invertebrate BAF was available from the literature; default value was used.
Antimony	1	Based on EPA (2007), where concentration in earthworm is equivalent to the concentration in soil.
Arsenic	0.258	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 53 BAFs ranging from 0.006 to 0.925 compiled from multiple sources; median BAF was 0.224.
Cadmium	17.105	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 226 BAFs ranging from 0.253 to 190 compiled from multiple sources; median BAF was 7.708.
Chromium	1.099	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 67 BAFs ranging from 0.021 to 11.416 compiled from multiple sources; median BAF was 0.306.
Cobalt	0.122	Based on the BAF reported by reported in EPA (2007).
Copper	0.754	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 197 BAFs ranging from 0.002 to 5.492 compiled from multiple sources; median BAF was 0.515.
Lead	3.342	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 245 BAFs ranging from 0 to 228.261 compiled from multiple sources; median BAF was 0.266.
Manganese	0.064	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 36 BAFs ranging from 0.012 to 0.228 compiled from multiple sources; median BAF was 0.054.
Mercury	5.231	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 30 BAFs ranging from 0.030 to 33 compiled from multiple sources; median BAF was 1.693.
Nickel	1.656	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 31 BAFs ranging from 0.033 to 7.802 compiled from multiple sources; The median BAF was 1.059.
Selenium	1.798	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 14 BAFs ranging from 0.300 to 13.733 compiled from one study; median BAF was 0.985.
Vanadium	0.042	Based on the BAF reported by reported in EPA (2007).
Zinc	5.766	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a) ; mean was based on 244 BAFs ranging from 0.025 to 49.51 compiled from multiple sources; median BAF was 3.201.
PAHs		
2-Methylnaphthalene	4.4	Based on the naphthalene BAF.
Benzo(a)pyrene	1.33	Based on the BAF reported by reported in EPA (2007).
Naphthalene	4.4	Based on the BAF reported by reported in EPA (2007).
Total PAHs	2.87	Based on the average BAF of the two individual PAHs with BAFs (benzo[a]pyrene and naphthalene) reported in EPA (2007).

Table 7. Earthworm BAFs Used in the ERA

Chemical	BAF (dw/dw)	Source and Details on Selected Value
Phthalates		
BEHP	1	No invertebrate BAF was available from the literature; default value was used.
Butyl benzyl phthalate	1	No invertebrate BAF was available from the literature; default value was used.
Di-n-butyl phthalate	1	No invertebrate BAF was available from the literature; default value was used.
Other SVOCs		
Benzoic acid	1	No invertebrate BAF was available from the literature; default value was used.
Biphenyl	1	No invertebrate BAF was available from the literature; default value was used.
Hexachlorobenzene	1	No invertebrate BAF was available from the literature; default value was used.
Pentachlorophenol	1	No invertebrate BAF was available from the literature; default value was used.
Phenol	1	No invertebrate BAF was available from the literature; default value was used.
PCBs		
Total PCBs	8.909	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998a); mean was based on 32 BAFs ranging from 0 to 65.227 compiled from multiple sources; median BAF was 6.667.
Pesticides		
Total DDTs	11.2	Based on the BAF reported by reported in EPA (2007).
delta-BHC	1	No invertebrate BAF was available from the literature; default value was used.
Methoxychlor	1	No invertebrate BAF was available from the literature; default value was used.
VOCs		
Acetone	1	No invertebrate BAF was available from the literature; default value was used.
Ethylbenzene	1	No invertebrate BAF was available from the literature; default value was used.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 8. Small Mammal BAFs Used in the ERA

Chemical	BAF (dw/dw[a])	Source and Details on Selected Value
Metals		
Aluminum	1.0	No small mammal BAF was available from the literature; default value was used.
Arsenic	0.0063	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 72 BAFs compiled from multiple sources, ranging from 0 to 0.071; median BAF was 0.0025.
Barium	0.0696	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 14 BAFs ranging from 0.0144 to 0.253 compiled from multiple sources; median BAF was 0.0566.
Cadmium	1.9902	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 99 BAFs ranging from 0.0153 to 69.561 compiled from multiple sources; median BAF was 0.3333.
Chromium	0.1382	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 38 BAFs ranging from 0.0314 to 0.8 compiled from multiple sources; median BAF was 0.846.
Cobalt	0.0371	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 15 BAFs ranging from 0.0101 to 0.18 compiled from multiple sources; median BAF was 0.0205.
Copper	0.42	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 76 BAFs ranging from 0.0044 to 1.398 compiled from multiple sources; median BAF was 0.1963.
Lead	0.1615	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 138 BAFs ranging from 0.0031 to 2.659; compiled from multiple sources; median BAF was 0.1054.
Mercury	0.1244	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 18 BAFs ranging from 0.0183 to 1.046 compiled from multiple sources; median BAF was 0.0543.
Nickel	0.2799	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 43 BAFs ranging from 0 to 1.143 compiled from multiple sources; median BAF was 0.2488.
Selenium	0.3464	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 35 BAFs ranging from 0 to 1.754 compiled from multiple sources; median BAF was 0.1619.
Vanadium	0.0123	Based on BAF reported in EPA (2007).
Zinc	1.3352	Based on the mean BAF reported by Lockheed-Martin Energy Systems (1998b); mean was based on 103 BAFs ranging from 0.0051 to 16.364 compiled from multiple sources; median BAF was 0.7717.
PAHs		
Benzo(a)pyrene	0.001	Based on EPA (2007) which reported that uptake of PAHs is assumed to be negligible.
Total PAHs	0.001	Based on EPA (2007) which reported that uptake of PAHs is assumed to be negligible.
Phthalates		
BEHP	1.0	No small mammal BAF was available from the literature; default value was used.
Butyl benzyl phthalate	1.0	No small mammal BAF was available from the literature; default value was used.
Di-n-butyl phthalate	1.0	No small mammal BAF was available from the literature; default value was used.

Table 8. Small Mammal BAFs Used in the ERA

Chemical	BAF (dw/dw[a])	Source and Details on Selected Value
Other SVOCs		
Hexachlorobenzene	1.0	No small mammal BAF was available from the literature; default value was used.
Pentachlorophenol	1.0	No small mammal BAF was available from the literature; default value was used.
Phenol		
PCBs		
Total PCBs	0.45[b]	Based on data presented in Moore et al. (2003); the small-mammal BAF (needed to estimated COPC concentrations in red-tailed hawk prey) was calculated as a weighted average of the mean reported short-tailed shrew BAF (1.2) and white-footed mouse BAF (0.2) using the following equation: $BAF_{mammal} = ([BAF_{mouse} \times 0.75]+[BAF_{shrew} \times 0.25])$.
Pesticides		
Total DDTs	$C_{mammal} = ([C_{plant} \times 0.75]+[C_{invert} \times 0.25]) \times 4.83$[e]	Based on data presented in EPA (2007); EPA (2007) reported an uptake factor of 4.83 from prey concentrations to the concentration in mammal tissue. The concentration in mammals was calculated assuming 75% plant-eating mammals and 25% invertebrate-eating mammals based on the assumption that the red-tailed hawk small mammal diet is primarily plant-eating mammals (Csuti et al. 2001; EPA 1993; Marshall et al. 2003).
delta-BHC	1.0	No small mammal BAF was available from the literature; default value was used.
Methoxychlor	1.0	No small mammal BAF was available from the literature; default value was used.
VOCs		
Acetone	1.0	No small mammal BAF was available from the literature; default value was used.

[a] All BAFs are expressed as the ratio of tissue concentration (in dry weight) over soil concentration (in dry weight), except where noted.

[b] For this BAF, tissue concentration is expressed as wet weight and soil is expressed as dry weight.

BAF – bioaccumulation factor
BEHP – bis(2-ethylhexyl) phthalate
BHC – benzene hexachloride
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPA – US Environmental Protection Agency
ERA – ecological risk assessment
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
VOC – volatile organic compound

Table 9. Log K_{ow} Values Used to Derive Plant BAFs

Chemical	Log K_{ow} [a]
BEHP	7.5
Di-n-butyl phthalate	4.29
Hexachlorobenzene	5.73
Phenol	1.46
Total PCBs	6.7[b]
delta-BHC	4.14
Methoxychlor	4.88
Acetone	-0.24
Ethylbenzene	3.54

[a] Log K_{OW} based on ATSDR (2006).

[b] Log K_{OW} based on average of PCB Aroclors 1254 and 1260.

BAF – bioaccumulation factor

BEHP – bis(2-ethylhexyl) phthalate

BHC – benzene hexachloride

PCB – polychlorinated biphenyl

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ATTACHMENT 3: EXPOSURE POINT CONCENTRATIONS

Exposure point concentrations (EPCs) in tissue and sediment were calculated in order to estimate exposure concentrations (as tissue residues or dietary doses) for fish and wildlife receptors of concern (ROCs). Sediment and soil EPCs (EPC_{sed} and EPC_{soil}) were represented by a upper confidence limit on the mean (UCL) concentration calculated using ProUCL 4.00.04 (EPA 2009), which includes provisions for handling non-detected values (EPA 2007) if sufficient data (i.e., six or more detected concentrations) are available. The UCL recommended by ProUCL was used as the EPC_{sed} or EPC_{soil} for the risk assessment, unless the UCL was greater than the maximum concentration. If the UCL was greater than the maximum concentration, then the maximum concentration was used to represent the EPC_{sed} or EPC_{soil} for the risk assessment. If sufficient data were not available to calculate a UCL using ProUCL 4.00.04, the EPC_{sed} or EPC_{soil} was set equal to one-half of the maximum reporting limit (RL) (if no detected results were available) or set equal to the maximum detect or one-half the maximum RL, whichever was greater. Tables 1 and 2 present the summary statistics and selected EPC_{sed} or EPC_{soil} values. These values were used to estimate tissue concentrations (EPC_{prey}) using biota-sediment accumulation factors (BSAFs) or bioaccumulation factors (BAFs), and receptor-specific assumptions. Details on how BSAFs, BAFs, and assumptions were selected are presented in Attachment 2.

Table 1. Wetland Soil EPCs and Summary Statistics for the Baseline ERA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	EPC_{soil}	Selected Statistic
Metals								
Aluminum	mg/kg dw	5/5	12,100	na	9,500	9,500	12,000	Maximum detect
Arsenic	mg/kg dw	71/71	53.1	na	8	8	9.3	95% H-UCL
Cadmium	mg/kg dw	63/71	4	0.4 U	1	0.9	1	95% KM (BCA) UCL
Cobalt	mg/kg dw	71/71	34.3	na	10	10	12	95% modified-t UCL
Copper	mg/kg dw	71/71	1,240 J	na	72	72	150	95% Chebyshev (Mean, Sd) UCL
Lead	mg/kg dw	71/71	320	na	60	60	78	95% H-UCL
Mercury	mg/kg dw	64/71	0.4	0.26 U	0.2	0.1	0.16	95% KM (BCA) UCL
Nickel	mg/kg dw	71/71	48	na	20	20	24	95% approximate gamma UCL
Selenium	mg/kg dw	3/71	1.1	3 U	0.8	0.5	1.5	half maximum RL
Vanadium	mg/kg dw	71/71	148	na	70	70	74	95% approximate gamma UCL
Zinc	mg/kg dw	71/71	748	na	200	200	240	95% H-UCL
PAHs								
Total PAHs	µg/kg dw	70/71	69,000	2,770 U	4,000	3,000	8,300	95% KM (Chebyshev) UCL
PCBs								
Total PCBs	µg/kg dw	46/71	4,200	990 U	500	300	680	95% KM (Chebyshev) UCL
Pesticides								
Total DDTs	µg/kg dw	70/71	46,000	130 U	3,000	3,000	8,500	97.5% KM (Chebyshev) UCL

[a] The mean value is equal to the average of all detected values and one-half of the RL for all non-detect values.

BCA – bias-corrected accelerated
COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
ERA – ecological risk assessment
J-qualifier – estimated concentration
KM – Kaplan-Meier
na – not applicable
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
UCL – upper confidence limit on the mean
U-qualifier – not detected at given concentration

Table 2. Sediment EPCs and Summary Statistics for the Baseline ERA

COPC	Unit	Detection Frequency (ratio)	Maximum Detection	Maximum RL	Mean Detect	Mean Value[a]	EPC_{sed}	Selected Statistic
Metals								
Arsenic	mg/kg dw	11/11	7	na	6	6	6.4	95% Student's-t UCL
Cadmium	mg/kg dw	8/11	2	0.7 U	2	2	2	maximum detect[b]
Cobalt	mg/kg dw	11/11	15	na	13	13	14	95% Student's-t UCL
Copper	mg/kg dw	11/11	72	na	53	53	72	maximum detect[c]
Lead	mg/kg dw	11/11	56	na	40	40	56	maximum detect[d]
Mercury	mg/kg dw	1/11	0.2 J	0.3 U	0.2	0.2	0.2	maximum detect
Nickel	mg/kg dw	11/11	31	na	24	24	27	95% Student's-t UCL
Vanadium	mg/kg dw	11/11	74	na	60	60	67	95% Student's-t UCL
Zinc	mg/kg dw	11/11	229	na	200	200	200	95% Student's-t UCL
PAHs								
Total PAHs	µg/kg dw	11/11	1,060	na	560	560	740	95% Student's-t UCL
	mg/kg OC	11/11	19.8	na	8.9	8.9	12	95% Student's-t UCL
PCBs								
Total PCBs	µg/kg dw	7/11	131	49 U	110	80	120	95% KM (percentile bootstrap) UCL
	mg/kg OC	7/11	1.83	2.5 U	1.4	1.1	1.4	95% KM (percentile bootstrap) UCL
Pesticides								
Total DDTs	µg/kg dw	11/11	250	na	160	160	200	95% Student's-t UCL
	mg/kg OC	11/11	3.7 JN	na	2.3	2.3	2.7	95% Student's-t UCL

[a] The mean value is equal to the average of all detected values and on-half of the RL for all non-detect values.

[b] All detected values were equal, and thus there were too few unique values for use in ProUCL.

[c] ProUCL recommended UCL (78) is greater than the maximum detected concentration, therefore the maximum concentration was selected as the EPC_{sed}.

[d] ProUCL recommended UCL (62) is greater than the maximum detected concentration, therefore the maximum concentration was selected as the EPC_{sed}.

COPC – contaminant of potential concern
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
EPC – exposure point concentration
ERA – ecological risk assessment
J-qualifier – estimated concentration
N-qualifier – tentative identification
na – not applicable
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
RL – reporting limit
UCL – upper confidence limit on the mean
U-qualifier – not detected at given concentration

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ATTACHMENT 4: BACKGROUND AND REFERENCE AREA CONCENTRATIONS

1.0 Introduction

US Environmental Protection Agency (EPA) guidance discusses two types of background concentrations, natural and anthropogenic. Natural background is defined as “naturally occurring substances present in the environment in forms that have not been influenced by human activity.” Anthropogenic background is defined as “natural and human-made substances present in the environment as a result of human activities (not specifically related to the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] site in question)” (EPA 2002). As recommended in EPA (2002) guidance, background concentrations of contaminants of potential concern (COPCs) at the Harbor Oil Study Area (when available) are discussed in the ecological risk assessment (ERA).

This attachment discusses background concentrations for metals as available from Oregon Department of Environmental Quality (DEQ) and reference area concentrations for organic compounds. The term reference area is used instead of background for organic compounds because no specific background concentrations that are representative of anthropogenic background have been selected or approved by EPA. Instead, concentrations from reference areas (urban areas within the vicinity of the Study Area) are presented for comparison with Study Area concentrations.

This attachment presents the background or reference area concentrations of COPCs identified in the ERA. Sources of background or reference area concentrations for the Harbor Oil ERA include the following:

- DEQ’s Memorandum from Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002): This memorandum presents regional soil background concentrations for metals, including arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc.
- DEQ’s Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment (DEQ 2007). This document presents regional soil and sediment background concentrations for metals, including arsenic.
- Natural Background Soils Metals Concentrations in Washington State Toxics Cleanup Program (Ecology 1994): This document presents regional soil background concentrations from Washington State for various metals, including metals not included in DEQ (2002) (e.g., aluminum and manganese).
- US Geological Survey (USGS) national background concentrations for metals (USGS 2001): For two metal COPCs (i.e., barium and vanadium), no regional background values were presented in DEQ (2002) or Ecology

(1994), so the median national soil background values reported by the USGS (2001) were used. National background values for twenty additional metals are also presented in this document.

- Radio Tower Site (URS 2000): Five samples were collected as part of a preliminary soil investigation at the Radio Tower Site across N Force Avenue from the Study Area. One of these samples was designated as a "background location" for the sampling event, but because concentrations at this location were generally similar to the other four samples, all samples from the Radio Tower Site were used to represent reference area concentrations for the ERA. Samples were analyzed for hydrocarbons, metals, pesticides, herbicides, and semi-volatile organic compounds (SVOCs).
- DEQ's Columbia Slough Sediment Project (DEQ 2005): Baseline sediment concentrations for the Columbia Slough, which drains over 30,000 acres of urban land in the City of Portland, were used to represent reference area concentrations for the ERA. These baseline maxima concentrations are calculated values meant to reflect the upper end of the range of concentrations throughout the slough (i.e., maximum concentrations excluding those associated with a particular source). These concentrations are relevant because they indicate the concentrations of chemicals present in the watershed associated with historical and current land uses (e.g., urban activities such runoff from roads, agricultural runoff). Concentrations were developed from samples taken since the early 1990s, and are available for volatile organic compounds (VOCs), phthalates, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals.

The Radio Tower Site and the Columbia Slough are shown on Figure 1 to provide information regarding the proximity of these regional sources to the Harbor Oil Study Area.

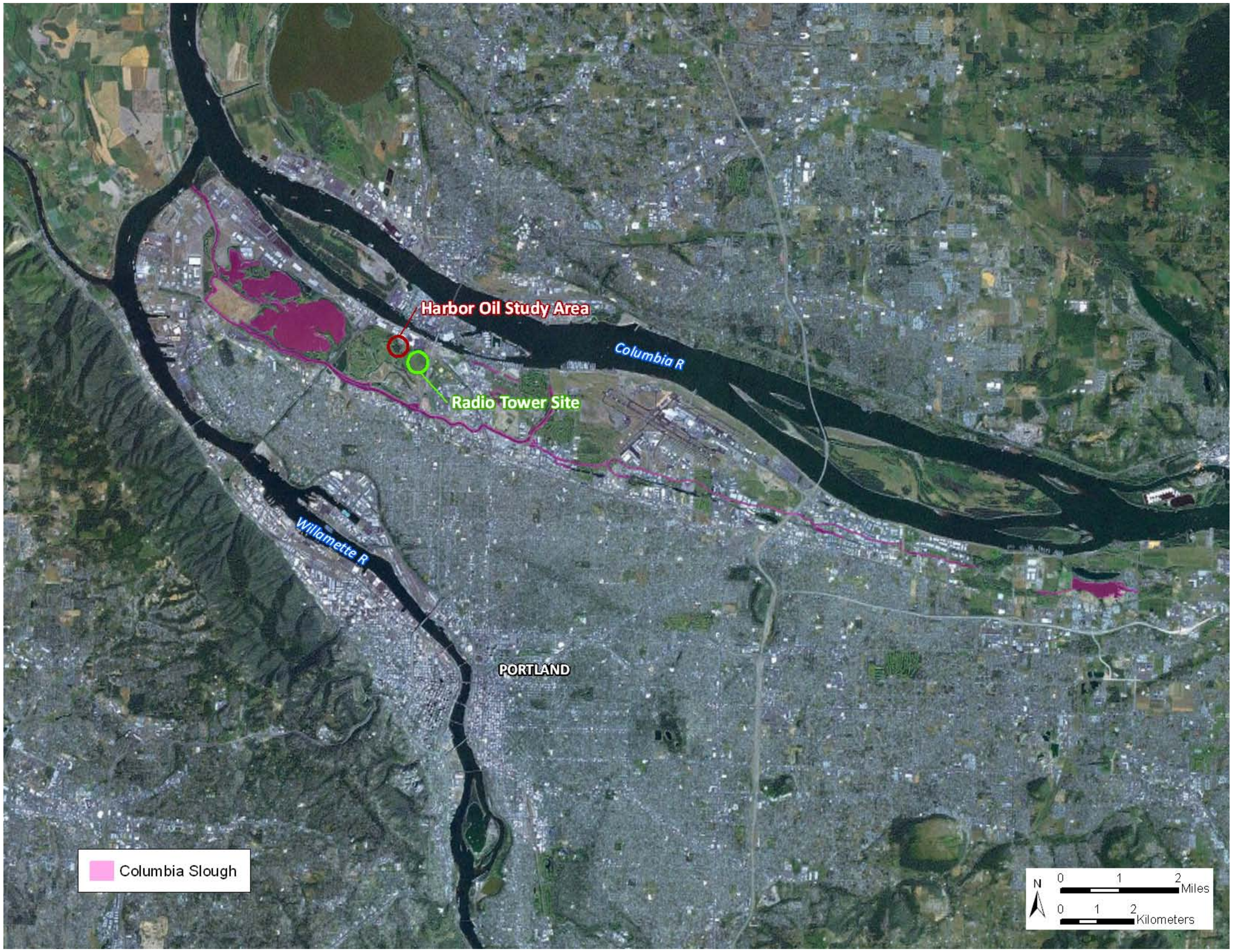

Figure 1. Locations of regional studies **used to define reference area concentrations**

Background or reference area concentrations in the ERA were used only for wildlife COPCs with lowest-observed-apparent-effects level (LOAEL) hazard quotients (HQs) greater than 1.0 and for benthic invertebrate COPCs with probably effects concentration (PEC) or probable effects level (PEL) exceedances greater than 1.0. Background or reference area concentrations of all terrestrial invertebrate COPCs were evaluated. These included 13 metals (i.e., aluminum, arsenic, barium, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, vanadium, and zinc), 6 individual PAHs (i.e., benzo[a]anthracene, benzo[a]pyrene, chrysene, fluoranthene, phenanthrene, and pyrene), total high-molecular-weight polycyclic aromatic hydrocarbons (HPAHs), total polychlorinated biphenyls (PCBs), 2,4'-dichlorodiphenyldichloroethane (DDD), 4,4'-DDD, 4,4'-dichlorodiphenyldichloroethylene (DDE), and total dichlorodiphenyltrichloroethanes (DDTs). Table 1 presents all of the selected background or reference area concentrations and sources of concentrations used in the ERA. Sections 2.0 through 5.0 present additional details on the selected background and reference area values.

Table 1. Summary of Selected Soil and Sediment Background or Reference Area Concentrations Used in the ERA

COPC	Unit (dw)	Background or Reference Area Concentration[a]		Source
		Soil	Sediment	
Metals				
Aluminum	mg/kg	37,200	37,200[b]	Ecology (1994)
Arsenic	mg/kg	7	7 – 7.9	DEQ (2002, 2007)
Barium	mg/kg	502	502[b]	USGS – 50th percentile (2001)
Cadmium	mg/kg	1	0.5 – 1	DEQ (2002, 2007)
Chromium	mg/kg	42	30	DEQ (2002)
Copper	mg/kg	36	12	DEQ (2002)
Lead	mg/kg	17	2.0 – 17	DEQ (2002, 2007)
Manganese	mg/kg	1,100	1,100[b]	Ecology (1994)
Mercury	mg/kg	0.07	0.07 – 0.2	DEQ (2002, 2007)
Nickel	mg/kg	38	20	DEQ (2002)
Selenium	mg/kg	2	0.4 – 2	DEQ (2002, 2007)
Vanadium	mg/kg	67.3	67.3[b]	USGS – 50th percentile (2001)
Zinc	mg/kg	86	53	DEQ (2002)
PAHs				
Benzo(a)anthracene	µg/kg	4.5 – 33	72 – 87	URS (2000); DEQ (2005)
Benzo(a)pyrene	µg/kg	5.3 – 39	90 – 100	URS (2000); DEQ (2005)
Chrysene	µg/kg	6.7 – 51	103 – 129	URS (2000); DEQ (2005)
Fluoranthene	µg/kg	7.3 – 53	132 – 144	URS (2000); DEQ (2005)
Phenanthrene	µg/kg	14 – 25	80 – 88	URS (2000); DEQ (2005)
Pyrene	µg/kg	8.4 – 67	196 – 196	URS (2000); DEQ (2005)
Total HPAHs	µg/kg	54 – 388	1,010 – 1,243	URS (2000); DEQ (2005)
Total PAHs	µg/kg	68 – 427	1,073 – 1,078	URS (2000); DEQ (2005)

Table 1. Summary of Selected Soil and Sediment Background or Reference Area Concentrations Used in the ERA

COPC	Unit (dw)	Background or Reference Area Concentration[a]		Source
		Soil	Sediment	
PCBs				
Total PCBs	µg/kg	23 – 24[c]	23 – 24	DEQ (2005)
Pesticides				
2,4'-DDD	µg/kg	5 – 15[d]	6.1 – 6.7	URS (2000); DEQ (2005)
4,4'-DDD	µg/kg	5 – 15[d]	6.1 – 6.7	URS (2000); DEQ (2005)
4,4'-DDE	µg/kg	5 – 110[d]	7 – 9.8	URS (2000); DEQ (2005)
Total DDTs	µg/kg	15 – 355[c]	16 – 19	URS (2000); DEQ (2005)

[a] Concentrations for metals are representative of background concentrations, and concentrations for organic compounds are representative of reference area concentrations.
[b] No sediment background value is available; sediment background value is based on soil.
[c] No soil background value is available; soil background value is based on sediment.
[d] The low end of this range is the reporting limit; the concentration was not detected.

COPC – contaminant of potential concern
dw – dry weight
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
Ecology – Washington State Department of Ecology
ERA – ecological risk assessment
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
USGS – US Geological Survey

In addition, a surface water background concentration of 9 µg/L was selected for copper based on the reported default freshwater background concentration reported by DEQ (2002).

2.0 Metals

Background metals concentrations in soil and sediment were primarily based on values reported in DEQ's Memorandum from the Toxicology Workgroup to DEQ Cleanup Program Managers Regarding Default Background Concentrations for Metals (DEQ 2002). For mercury, the soil background value (0.07 mg/kg dw) was based on DEQ (2002). A range of sediment concentrations (0.07 to 0.2 mg/kg dw) was used to represent mercury sediment background concentrations at the Study Area based on the DEQ (2002) (regional background sediment value was 0.2 mg/kg dw), and DEQ (2007) (regional background sediment value was 0.07 mg/kg dw).

For metals that had no regional values reported in that DEQ (2002), including aluminum and manganese, background soil concentrations reported in Natural Background Soils Metals Concentrations in Washington State Toxics Cleanup Program (Ecology 1994) were used to represent soil and sediment background concentrations. For two metals COPCs, barium and vanadium, no regional background values were presented in DEQ (2002) or Ecology (1994), so the median (50^{th} percentile) national soil background values reported in USGS national background concentrations for metals (USGS 2001) were used to represent soil and sediment background concentrations. Based on the maps presented in USGS (2001), the Portland regional levels of barium and vanadium were actually greater than the national 50th percentile values; therefore, the selected background values for barium and vanadium are conservative background values for the Portland regional area.

3.0 PAHs

Reference area sediment PAH concentrations were available from several sources:

- A range of PAH concentrations reported for all PAH COPCs from DEQ's Columbia Slough Sediment Project (2005), which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source.
- A range of PAH concentrations reported for all individual PAH COPCs from five samples taken at the Radio Tower Site (URS 2000).

A range of PAH concentrations reported in the two above sources was used to represent reference area sediment and soil PAH concentrations at the Study Area for each PAH COPC. Table 2 presents the range of PAH COPC concentrations reported in the two sources. Specific background concentrations for PAHs have not been established by EPA or DEQ.

Table 2. Summary of PAH Reference Area Concentrations

COPC	Range of Concentrations (µg/kg dw)	
	Sediment (Columbia Slough)[a]	Soil (Radio Tower Site)[b]
Benzo(a)anthracene	72 – 87	4.5 – 33
Benzo(a)pyrene	90 – 100	5.3 – 39
Chrysene	103 – 129	6.7 – 51
Fluoranthene	132 – 144	7.3 – 53
Phenanthrene	80 – 88	14 – 25
Pyrene	196 – 196	8.4 – 67
Total HPAHs	1,010 – 1,243	54– 388[c]
Total PAHs	1,073 – 1,078	68 – 427[c]

[a] DEQ (2005).
[b] URS (2000).
[c] Non-detected values were treated as one-half the reporting limits for calculating sums.

COPC – contaminant of potential concern
DEQ – Oregon Department of Environmental Quality
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
na – not available
PAH – polycyclic aromatic hydrocarbon

4.0 PCBs

Reference area concentrations for total PCBs are available from one source, DEQ's Columbia Slough Sediment Project (2005). A range of 23 to 24 µg/kg dw (Aroclor 1254) was calculated from the data, which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source. This range was used to represent reference area sediment and soil total PCB concentrations for comparison to Harbor Oil data. Total PCBs were not analyzed in the samples collected from the Radio Tower Site. Specific background concentrations for total PCBs have not been established by EPA or DEQ.

5.0 DDTs

Reference area sediment concentrations for total DDTs were available from several sources, as noted below:

- A range of DDD, DDE, and total DDT concentrations reported DEQ's Columbia Slough Sediment Project (2005), which represents calculated baseline maxima concentrations meant to reflect the upper end of the range of sediment concentrations throughout the slough that are not associated with a particular source.
- A range concentrations for 4,4'-DDD, 4,4'-DDE, and total DDTs from five samples collected at the Radio Tower Site were reported in the preliminary soil investigation for that site (URS 2000). The range of total DDTs was 15 to 355 µg/kg dw. It should be noted that the maximum value (355 µg/kg dw) was substantially higher than the next highest concentration (55 µg/kg dw). However, because of the patchy nature of DDT concentrations in the region and because there was no indication that the maximum concentration was linked to a specific source, all fives samples were determined to be acceptable to represent total DDT reference area concentrations in the ERA.

A range of DDT concentrations reported in the two above sources were used to represent reference area sediment and soil DDT concentrations at the Study Area for each of the DDT COPCs: 2,4'-DDD, 4,4'-DDD, 4,4'-DDE, and total DDTs. Table 3 presents the range of DDT COPC concentrations reported in the two sources. Specific background concentrations for DDD, DDE, or total DDTs have not been established by EPA or DEQ.

Table 3. Summary of DDT Reference Area Concentrations

	Range of Concentrations (µg/kg dw)	
COPC	**Sediment (Columbia Slough)[a]**	**Soil (Radio Tower)[b]**
2,4'-DDD	6.1 – 6.7[c]	5[d] – 15[e]
4,4'-DDD	6.1 – 6.7[c]	5[d] – 15
4,4'-DDE	7 – 9.8[f]	5[d] – 110

Table 3. Summary of DDT Reference Area Concentrations

COPC	Range of Concentrations (µg/kg dw)	
	Sediment (Columbia Slough)[a]	Soil (Radio Tower)[b]
Total DDTs	16 – 19	15[d] – 355

a DEQ (2005).

b URS (2000).

c Reference area concentrations for 2,4'-DDD and 4,4'-DDD are based on reported DDD concentration.

d The low end of this range is the reporting limit; the concentration was not detected.

e Reference area concentration for 2,4'-DDD is based on 4,4'-DDD reference area concentration.

f Reference area concentration for 4,4'-DDE is based on reported DDE concentration.

COPC – contaminant of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DEQ – Oregon Department of Environmental Quality
dw – dry weight

6.0 References

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